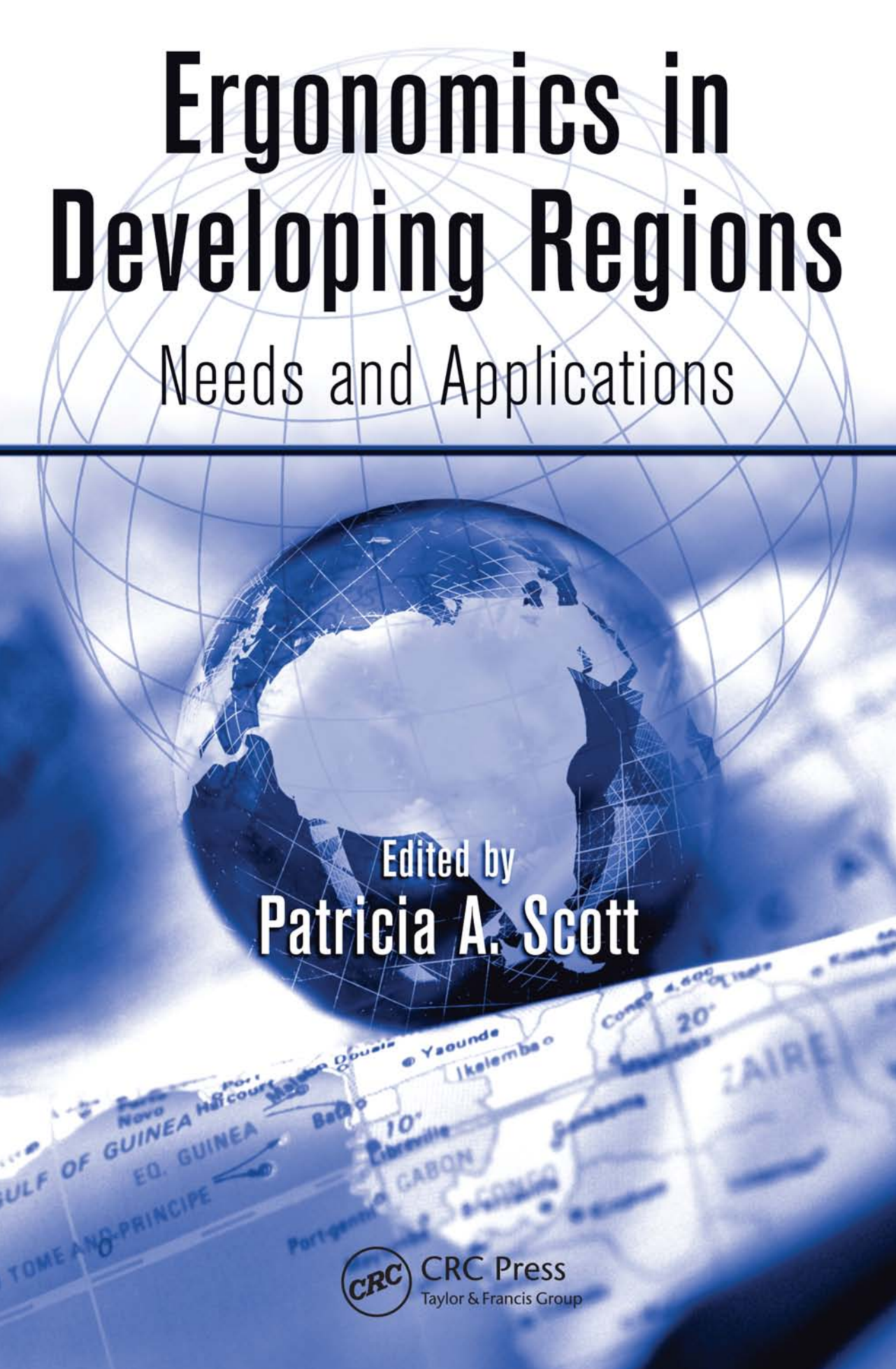
Ergonomics in Developing Regions

Needs and Applications



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Ergonomics in Developing Regions

Needs and Applications

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Ergonomics in Developing Regions

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Patricia A. Scott

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Preface

Appreciation of the role of ergonomics in improving and enriching the conditions of humans at work is burgeoning worldwide. How could it be otherwise, given the fact that ergonomics has at its core not merely understanding but improving working conditions and work practices, in a way that "humanizes" working lives by reducing physical and mental stress, and minimizing drudgery, while facilitating initiative, optimizing creativity, self-esteem, and a sense of recompense for effort expended; in short—"joie de vivre."

Yet, this salutary effort is more widely publicized, better resourced (and as a consequence more appreciated) where it is least needed, namely in a modern, well-established, industrialized, affluent, human-rights-oriented, "developed" world in which a relatively small fraction of the human biomass is fortunate to reside. Arguably, 75% of humankind lives in another world, a world which is developing and industrializing, whose populace is under-resourced, undernourished, and largely denied its rights. This is a world in which human work, when you can get a job, is not done for self-enrichment but to secure basic survival of dependents who cannot themselves access the workplace, and where thousands of children grow up never having seen the inside of a school, but rather are sent out to work under the most appalling conditions.

Notwithstanding the forces of globalization, the gap between industrially advanced countries (IACs) or the "haves" and industrially developing countries (IDCs) or the "have-nots" is increasing. Poverty, deprivation, overpopulation, illiteracy, and suboptimal working conditions attend this scenario. This widening chasm, among other things, feeds discontent which, justified or not, exacerbates tensions. To the extent that this view is valid, the challenge for ergonomics is to contribute to a narrowing of the gap by recognizing that the vast majority of the biomass of humanity is engaged in basic IDC issues (Scott and Charteris, 2004).

It is in this world that ergonomics takes on a whole new meaning, a world where the amelioration of harsh working conditions is subservient to basic day-to-day survival. It is here, in what we euphemistically call the "informal sector," that human beings toil long hours at brutal tasks which none in the "advanced" world would tolerate; tasks long since legislated against in the developed world. Their needs are greater and tragically most often they are unaware that their conditions can in fact be dramatically improved. A core of dedicated endemic ergonomists work in this milieu, under-resourced and largely unsung, certainly often unappreciated, or perceived as another expense to drain the meager finances of a struggling company in a struggling region of the world.

This book is not a lament of suboptimal working conditions, but rather an eye-opening tribute to the resourcefulness and tenacity of developing world ergonomists whose simple interventions hugely and beneficially impact the lives of millions. It is worth noting that the better working conditions are, the higher the cost–benefit ratio is of further improving them, and one advantage the IDC ergonomists have over their IAC counterparts is that their interventions reap greater rewards, and the benefits they effect can be felt far beyond the working environment. Our book aims to fill the gap in an understanding of the global nature of ergonomics. The collected wisdom of First-World ergonomists is epitomized in the magisterial *Evaluation of Human Work* so ably pulled together by Wilson and Corlett (2005), and now in its third edition. This superb compilation, however, speaks to the world that is represented by its 51 contributors, not one of whom lives and works where

the human need for ergonomics is greatest. Our book, *Ergonomics in Developing Regions: Needs and Application*, aspires to fill that gap and to serve as a companion contribution to the total picture.

In the struggling-to-develop world, ergonomics theory is naturally less esoteric and its application more basic. Strategies are different where recipients of interventions exhibit the malaise of undernourishment, the resignation of ignorance of human rights, and where those who exploit the working poor do so less subtly because they know they can get away with it. This book chronicles the nuances of differences in aim, practice, and outcome when ergonomists tackle Developing-World problems from a Developing-World perspective. This book brings together accomplished IDC ergonomists from around the globe with expertise in diverse areas, and includes sections on the distinctive situations and requirements in developing areas, and the dire consequences of not addressing their needs effectively. Research projects and practical illustrations are cited to demonstrate the benefits of basic ergonomics interventions within diverse situations; and, acknowledging the shortage of ergonomists in all developing regions, several chapters cover various means of encouraging the workers themselves to use basic ergonomics principles to solve work-site problems for themselves. The contents of this book should prove useful to teachers and students interested in ergonomics whether in advanced industrialized countries or in struggling developing regions, helping the former group to gain insights into a world very different from their own, and the latter group to assist the underprivileged world to become viable contributors to the global economy. It should also be of benefit to ergonomics consultancies, and indeed all multinational organizations and companies who are concerned with the plight of workers subjected to unacceptable working conditions around the world.

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A final heartfelt appreciation to my husband, and colleague, Jack Charteris not only for his tolerance of my single, focused commitment to collating these works, but also for his nonstop positive criticism, insightful suggestions, and continuous encouragement over the last two years.

Patricia A. Scott, PhD

Editor

Patricia A. Scott has made contributions to ergonomics around the globe, and her teaching and consultancy work, particularly in the less developed countries, has for decades concentrated on bringing ergonomic principles and practices to these regions. It is here, where the need is greatest, that she has conducted ergonomics workshops under the aegis of the International Ergonomics Association (IEA), the International Labour Organization (ILO), and the Ergonomics Society of her native South Africa, both on her own and in company with some of the luminaries of international ergonomics.

A founding member of the Ergonomics Society of South Africa (ESSA), she has served both as secretary and chairperson of that society; she was also a member of the IEA Executive Committee and for two terms chaired its standing committee for ergonomics in industrially developing countries (IDCs). An emeritus professor of Rhodes University, Dr. Scott was head of the first full-time ergonomics degree program in South Africa. She has supervised over 20 postgraduate students and authored over 150 papers in international journals and chapters in books on the subject. She was chief editor of the journal *Ergonomics: SA*, where she encouraged the publication of the stalwart efforts of ergonomics research being conducted in IDCs around the globe. She coauthored the proceedings of the first International Ergonomics Conference in Africa jointly run by IEA/ESSA (1998) appearing under the title *Global Ergonomics* (Elsevier), and is a coauthor of the jointly sponsored IEA/International Commission on Occupational Health (ICOH) booklet *Ergonomics Guidelines: A Handbook for Occupational Health Professionals in Industrially Developing Countries*, now in press.

Patricia A. Scott is a fellow of the IEA. Her other national and international recognitions include election as a fellow of ESSA, receipt of the IEA's award for the "Promotion of Ergonomics in Industrially Developing Countries" (2003), and the Human Factors and Ergonomics Society's "Distinguished International Colleague Award" (2007).

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Part I

Distinctive Requirements of Developing Regions

1

The Development of, and the Need for, Ergonomics in Industrially Developing Countries

Patricia A. Scott

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1.1 Introduction

Although the International Ergonomics Association (IEA) logo epitomizes a "one world" concept, the dichotomy of a First World–Third World divide, conjured from an Eighteenth Century Industrial Revolution ethos of "haves" and "have nots," remains. Whatever politically correct term is used, this divide is a central theme in international relations generally, and is perpetuated in the field of ergonomics which realistically recognizes the dichotomy between industrially advanced countries (IACs) and industrially developing countries (IDCs). The former include the more affluent- and technology-driven regions, while the latter incorporate the less developed, poorer nations of the world, which are manually driven, and which arguably make up roughly three quarters of the world's working population. Recent World Bank figures indicate that 75% of sub-Saharan Africa and South Central Asia live on less than US$ 2 per day. Scott and Charteris (2004) have enumerated the broad characteristics shared by IDCs: low standards of living, limited education, high rates of population growth, high levels of unemployment, significant dependence on subsistence agriculture, low productivity and vulnerability in international relations; a package which these authors argue is synonymous with "deprivation dulling aspiration." In other words, many individuals in these countries are forced to focus on day-to-day survival, and are not able to plan for the future. Hence, IDCs tend to be the countries in debt and unable to get out of debt, and are therefore locked into negative economic scenarios. Despite the current concept of globalization, in a world united by advanced technology the "Digital Age" is

instrumental in actually widening the disparity between IACs and IDCs, and ergonomics has a heavy responsibility to contribute toward stemming this growing gap, and to unify the drive to enhance the quality of life worldwide (Scott and Charteris, 2004).

The dichotomy should not be overplayed however, for it is evident that there are ranges of overlap between and within these two worlds, and one needs to recognize that specific suboptimal work-sites can be found in both IACs and IDCs. Having acknowledged that there are universal work-site problems, it is nevertheless time we recognize that IACs experience nothing like the scale of problems, within and beyond the workplace, which are manifest in IDCs. The incidence of impoverished work environments is significantly higher in developing regions, and their economies significantly weaker. In developing countries the vast bulk of the population live in extreme poverty, with menial housing and minimal nutritional intake, resulting in poor health and a low work capacity. Most people living under these conditions have very limited education, and are therefore only able to find employment doing semiskilled or unskilled heavy manual labor, often endured under extreme environmental and working conditions. While some have depicted this negative scenario as a "vicious circle" (O'Neill, 2000), Scott (2001a and b, 2005) argues that it is in fact a "negative spiral" with the situation getting progressively worse, and the need for sound ergonomics becoming more critical (see Figure 1.1).

The objective of this chapter is therefore twofold: to provide some insights into the position of ergonomics in developing areas, recognizing that while much progress has been made over the last decade, we have only just begun to diminish the problems, and to propose a possible course of dynamic and focused action for the future. In order to incorporate input from a cross section of IDCs, the author has drawn on personal experiences

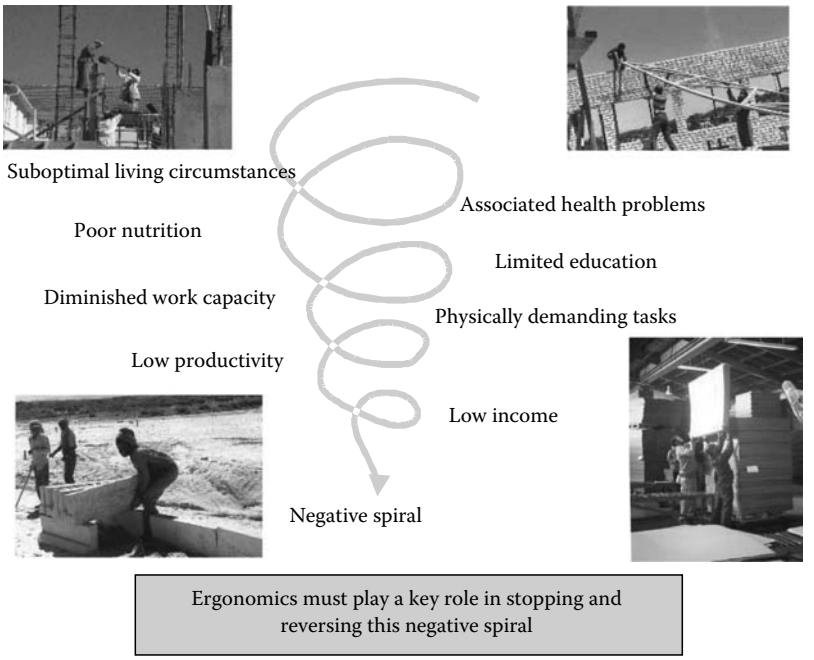

FIGURE 1.1
Compounding negative factors typical of IDC conditions.

in several developing areas over the last 20 years, as well as an ongoing interaction with local ergonomists in many regions recognized as IDCs. Although literature specific to these areas is limited, there are an increasing number of papers focusing on work being done in less developed countries which are available for those interested in these crucial ergonomics developments. Despite common trends and problems, each region does have its own perception of its specific situation and the role that ergonomics can play in improving working conditions. Hence the need for a book of this nature, incorporating examples of the good work being conducted in developing regions around the world. While some of this universally available information has been incorporated into this chapter, its main emphasis is to describe conditions in southern Africa as typifying the situation in IDCs generally. The focus on Africa, internationally recognized as the poorest continent, is not necessarily a limiting factor, particularly when seen in the light of the sentiment of the World Economic Forum held in South Africa in 2004, which was that the 'gifts' of the rich to the world of the poor, have in effect been exploitation followed by indifference. Given the recent international drive to improve the status of the African continent, it is crucial that ergonomists around the globe, together with the IEA, play their role in assisting Africa, and indeed all developing regions, to fulfill their potential to become more viable contributors on the world market. While many developed areas are inclined to ease their consciences by giving handouts (often not very appropriate, such as giving computers to semiliterate people in areas where the majority of the population does not have reliable electricity), over the last decade Scott has emphasized that the main objective of introducing ergonomics to these developing areas is to "help others help themselves" (Scott, 1996) through the spread of a basic theoretical knowledge of the principles of ergonomics, together with a clear understanding of the benefits of applying this knowledge within all work-sites, from small informal settings to large multinational corporations.

1.2 Harsh Reality

The cold reality of human-powered work, so evident in IDCs, is that loads of 50–100 kg are routinely lifted, and when they are lighter, frequencies of above 20 lifts per minute are commonly witnessed; pulling and pushing of masses in excess of 1000 kg are executed, often where coefficients of friction are high; work durations in excess of 8 h are commonplace, as are horrendous work conditions, with limited overall organization and little or no concern for the workers involved. Examples of physically demanding jobs and evidence of poor work organization are illustrated in the series of pictures presented in Figure 1.2, not chosen to dramatize extremes, but rather to document modal conditions. It is unfortunate that under such horrendous conditions, well-intentioned international guidelines, even when accessible, are often impossible to implement. These areas need a very specific focus in terms of work-site analysis, laboratory research, practical interventions, and appropriate (i.e., culturally acceptable) local guidelines.

Over the last decade there has been a steady increase in field investigations conducted within IDCs. A generic synopsis of the data collected on typical tasks executed in India, South America, and southern Africa is presented in Table 1.1, showing the range of masses moved and the frequencies of lifts per minute over shifts of varying lengths. In addition, when attempting to get some measure on how workers are responding to these physical loads, heart rate is probably the most commonly assessed

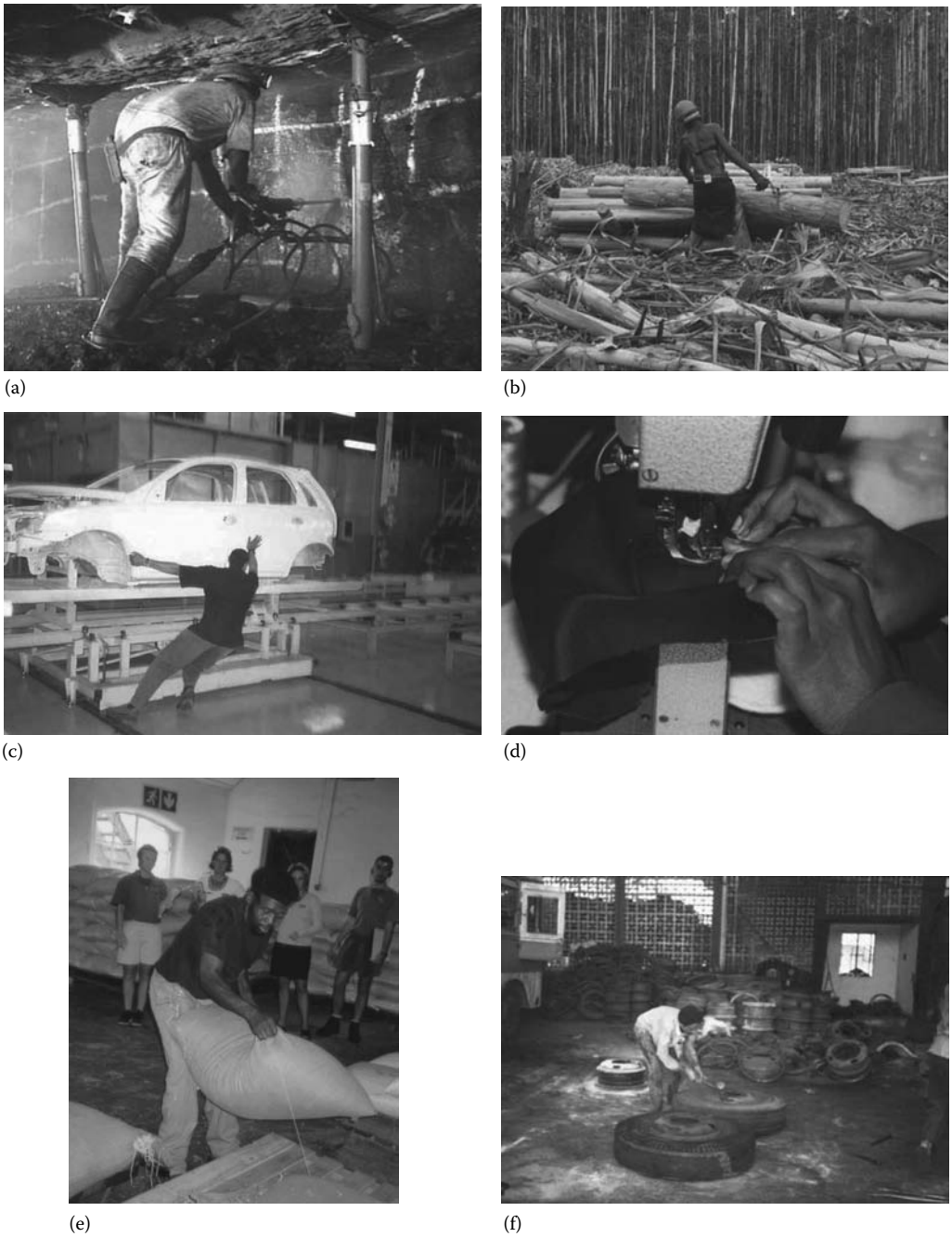

FIGURE 1.2
Examples of manual tasks executed on a daily basis in IDCs. (a) Mining, 2–3 km underground; (b) stacking logs of up to 140 kg; (c) pull/pushing vehicle frames of over 500 kg; (d) repetitive heavy-duty sewing for 10–12 h; (e) handling of awkward object of 60 kg; (f) car mechanics in an informal setting.

TABLE 1.1

Synopsis of Diverse Workloads and Cardiac Responses Assessed by Scott and Colleagues in South Africa Over a Decade (1996–2006)

Manual Tasks	Mass (kg)	Frequencies (Lifts/min)	Duration (h)	WHR (Beats/min)	Peak Heart Rate (Beats/min)
Loading/ unloading trucks	12–36	5–26	1–3	128	167
Bricking sorting	3 × 2 (6)	18–24	5–7	120	153
Shelf packing	6–40	5–16	3–6	123	162
Log stacking	10–110	5–14	3–6	117	185
Automotive pulling and pushing	200–1000	16–144 (per shift)	8	114	136

Source: Unpublished consultancy reports.
WHR, average working heart rate over a work-shift.

parameter, so included in the table are average heart rates over a work shift, together with peak heart rates recorded during the shift. Extremely high peak rates of up to 185 beats/min, with moderately high average rate of 114 beats/min, are reflective of intermittent work patterns where workers push at a high intensity for a short spell and then sit back and do nothing. This is indicative of "self-paced" work where the work/rest breaks are self-controlled. In addition several industries still "work to task" which results in many workers rushing to get the job done (particularly if it is out in the open under extreme environmental conditions) in order that they are able to go home early. Or in some cases, workers stay on to complete a second shift, which means they work for 16 h, while others may go on to other jobs, all in order to earn enough to feed themselves and numerous unemployed dependents. These elevated heart rates are an indication of the taxing physical requirements of the task, imposing unacceptable demands on predominately rural workers. Under such conditions, it is therefore essential to consider not only the demands of the job, but also the socioeconomic, nutritional, and health status of the manual laborers. This is an area where much research is still needed, and Table 1.2, based on the work of Christie and Scott (2005), illustrates the imbalance between daily nutritional intake and energy expenditure on a specific, but representative, small cohort of 30 forestry harvesters working during the summer months (temperatures well in excess of 30°C) in South Africa.

TABLE 1.2

An Example of the Imbalance between Nutritional Intake and Energy Expenditure

Recommended Daily Allocation (kJ)	Average Daily Intake (24 h) (kJ)	Work-Shift Intake (6 h) (kJ)	Energy Expenditure (kJ/Shift)	Deficit[a] (kJ)	Mass Lost per Shift (kg)
8000–11,000	5759	413	8947	3188	1.1–3.9

Source: Adopted from Christie, C.J. and Scott, P.A., *Ergonomics SA*, 1, 41, 2005.
[a] Deficit between total intake and energy output.

1.3 Past Developments and Present Situation

As we celebrated 50 years of the IEA, the immediate past president, Pierre Falzon, in his 2004–2005 annual report noted that the IEA now "covers a very large part of the world," and acknowledged that federated societies are predominantly from "developed countries," which he recognized as being more "affluent." While the registered societies may include a "large part of the world," it is of interest to note that the average membership of IDC societies is approximately 40, while in IACs it is about 500. When considering the ratio of the number of ergonomists to the general population, the imbalance is exacerbated. Two examples using approximate figures illustrate the point:

	Population (Million)	*Society Members*	*Ratio*
The Netherlands	16.3	500	1:32,600
India	1103.6	110	1:10,032,727

The past president commented that although Latin America has established several ergonomics societies over the past 10 years, "the expansion of the IEA is slowing down" (Falzon, 2005). Maybe the focus should not so much be on increasing the number of federated societies, but rather on reaching a far greater percentage of people within these societies; in other words, on helping the less developed societies to be more effective. He then went on to say that "in order for an ergonomics society to exist in a given country, the country must have reached a *sufficiently high level of development*" (italics my own). Unfortunately this appears to be the misconception of many, and as Scott (1999) reported, there is an inverse relationship between "knowledge of" and "need for" ergonomics, while Hendrick (1998) clearly stated that ergonomics has failed to reach areas where it is needed most, viz. *developing regions*. It is therefore imperative that the IEA and leading ergonomists within it make a far more concerted effort to reach these regions.

Fortunately, while Shahnavaz (1995) talked of ergonomics being in its "infancy" in IDCs, Scott (2003), in her final report of the standing committee for Ergonomics in IDCs, at the IEA Congress in Korea, commented on a growing awareness of, and commitment to, ergonomics in developing areas around the globe. It is clear that in response to the stalwart efforts of people like Weisner, Sen, Shahnavaz, and Kogi (to name but a few), the local populations in, for example, Chile, Brazil, India, Iran, Thailand, and Vietnam have been inspired to keep up the good ground-breaking work of such leaders and to develop ergonomics within their specific regions. The result is that "islands of excellence" within "vast oceans of deprivation" (Nag, 2001) are growing in number and in size, with local people continuing the work of the international "experts" who have advised them. All this activity holds great promise, but is still far from being enough.

1.4 Strengths, Weaknesses, and Challenges Facing Ergonomists in IDCs

On the credit side, a general receptiveness to ergonomics has been established in many needy countries, and an international network between some ergonomically sound

countries and some ergonomically emerging regions has been solidified. On the debit side, unless the international experts giving advice are sensitive to local conditions and local cultures, their efforts to be of assistance in these areas will not be successful. It is both arrogant and ignorant to lay the blame for the underdevelopment of ergonomics at the door of sociocultural differences between IDCs and IACs; for ergonomics is all about optimizing working conditions in broader contexts, not about sitting back and waiting for IDCs socioeconomical, educational, and political developments to emulate those of IACs before getting involved. In short, it is only by working with, and optimizing what is, that ergonomists can hope to effect change in the direction of what ought to be. As Shahnavaz (1995) has pointed out, one cannot apply First-World ergonomics theory to Third-World problems without substantial modifications to accommodate the indigenous workforces within local industries. Hence, the challenge is to recognize the specific endemic needs of disparate cultures, and to encourage culturally acceptable local involvement. It is gratifying to note that meaningful steps have been made over the last decade and more ergonomics societies have been established. The challenge now, is to keep the momentum going. This can be achieved through the three broad areas of education, certification, and research.

1.4.1 Education

Having created a basic awareness of ergonomics in a growing number of countries, the emphasis must now be on assisting IDCs to establish a solid knowledge base, together with the practical and beneficial application of this information, in order to improve the working conditions that so many manual laborers have been subjected to over the years. The key to the sustainable development of ergonomics is education—education at two levels.

First, at a basic level within industry itself, while at the same time creating a general public awareness of ergonomics. Two good examples of this are the now well-known and well-used "Roving Seminars" based on the ILO/IEA Checkpoints, and the WIND program developed and used in Asia. Over the last 10 years these programs have proved to be highly successful in the promotion of ergonomics, and in giving the local workers some concrete guidelines on how to identify problems and then to implement basic intervention strategies. The concept behind these workshops has been to encourage participation at all levels within a company, and to help the local enthusiasts in establishing an ethos of "co-operative co-responsibility" for the betterment of all (Scott, 1996). It is imperative that these Roving Seminars are continued and supported by the IEA. Scott (2005) reported on the success of these "generic" workshops as the first step for anyone interested in enhancing worker well-being and improving productivity (inclusive of employers and employees), and suggested that these should then be followed by more specific workshops conducted within a particular company. In the former, the basic concepts of ergonomics should be introduced, and although theory may dominate initially it is critical that the practical application of this knowledge is clearly demonstrated, and that at the practical level participants be encouraged to offer their inputs as soon as possible (Scott and Shahnavaz, 1997). In many work situations, manual laborers are often treated as inferior beings and if things go wrong it "must be their fault"; hence, the sooner one can get workers to regard their input as valued, the sooner they will become actively engaged in solving any problems. In this way floor workers learn to anticipate potential problems and their input will then be more proactive rather than reactive to a problem. Hence, those working at the "coal-face" can be very much part of the solution, and should not be assumed to be the cause of things going wrong. It is important to point out that basic and very effective interventions can be

(a) (b)

FIGURE 1.3
Example of (a) pre- and (b) post-low-cost intervention strategies. (In an automotive industry in Iran, with acknowledgment to M. Motamedzade.)

implemented at very little cost. In fact Scott (1996) and Kogi (1997) both strongly emphasize that as far as possible any means of improving the situation must be affordable and acceptable to the company. An example of low-cost modifications to the overall situation is presented in Figure 1.3, and these organizational changes will have a beneficial affect on the individual tasks executed within that particular area.

Once the general theory of ergonomics is understood, follow-up workshops within specific companies are necessary as the application of theoretical principles will differ substantially in, say, the sterile environment of a pharmaceutical company compared to the harsh external environment of the forestry industry. By following basic introductory steps, one can develop "ergonomics facilitators" within individual companies, where all concerned, including floor workers, supervisors, safety officers, occupational health personnel and union leaders, plus management (often initially the most reluctant to get on board), begin to develop mutual trust as they work together to improve overall work efficiency within the company.

Second, given the magnitude of the problems faced in IDCs, and the very limited number of experienced ergonomists in these regions, it is important to establish quality tertiary educational ergonomics programs within developing countries. While there are numerous examples of University courses being established in India, Iran, Malaysia, Brazil, Chile, and South Africa, much has still to be done to ensure that high academic and research standards in the discipline of ergonomics are achieved and maintained. This is an area in which the IEA and qualified ergonomists from well-resourced areas can play a major role, by establishing two-way exchanges with staff and students at universities in developing

areas. While this may be seen as a one-way flow of information, I am sure the "experts" from IACs will gain as much from the experience of witnessing a world they never knew (or simply did not acknowledge) even existed. Several distance and e-learning programs are also being developed and these too will contribute greatly to the growth of better qualified ergonomists in IDCs. Unfortunately in many of these regions, ergonomics is often thought to be just "common sense," and it is therefore imperative that any ergonomic application is based on sound scientific knowledge.

1.4.2 Certification

Once there are more qualified ergonomists in specific countries, the next critical step will be professional accreditation of these ergonomists. While there are many charlatan ergonomists universally, the problem is exacerbated in IDCs where there are so few qualified ergonomists, and where many are claiming to be ergonomists after having attended a short seminar or two on ergonomics. There is no doubt that this is where the Professional Standards and Education Committee of the IEA can make a major contribution, by assisting in the development of basic prerequisites for registration as an ergonomist. Scott (2001a, 2005) proposed a two-tier level for ergonomists in IDCs: First, the registered ergonomist, who must meet international standards in order to ensure top quality professional status, and secondly the "ergonomics facilitator," who must have a basic knowledge of ergonomics through regular attendance at recognized workshops and seminars, and who is then able to initiate and run in-house ergonomics programs with a cross section of employers and employees, thus facilitating an ergonomics ethos within the company. This is an area where regional ergonomics societies can be of assistance by regularly disseminating flyers, posters, and general "ergonomics hints" to be used by companies. One example of this, considering the importance of regular fluid intake particularly in hot climates, presented by Christie in the *Ergonomics Society of South Africa's Newsletter* (2003), is shown in Figure 1.4.

1.4.3 Research

For ergonomics programs to be effective in IDCs, it is essential to ensure that rigorous research, with a specific focus on work being done in IDCs by IDC workers, is conducted by scientists within these developing regions. The general information presented earlier in Tables 1.1 and 1.2 gives an indication that task demands are well in excess of accepted (not necessarily practiced) guidelines in advanced industries, and the IDC literature is replete with information on the low work capacity of rural manual laborers so evident in these developing countries. In addition, the ILO and WHO annually report on the horrendously high incidence of musculoskeletal problems, occupational diseases, and indeed fatalities. In such extreme situations the excellent, but more esoteric, research conducted in the laboratories of IACs is of scant practical benefit. It is therefore important that internationally recognized journals and conferences promote ergonomics research relevant to IDCs. There is a clear need to establish local normative databases on both indigenous workforces and on the physically demanding tasks they are required to carry out daily. Thereafter, it is necessary to quantify the benefits of ergonomics intervention by conducting holistic pre- and postanalysis of workers operating under diverse suboptimal conditions. One would then be able to tangibly demonstrate the benefits of such interventions to both employers and employees which in turn will strengthen their commitment to the implementation of ergonomic principles within the company.

Ergonomics: Useful Hints and Information for Members of ESSA
Fluid Replacement at Work

With any type of physical activity, an individual loses fluid through sweating and through water vapour in the air that is breathed out (Bean, 2002). Depending on the type of activity as well as the intensity and duration, fluid losses can be high and if not adequately replaced, dehydration will follow. This has been shown to have an adverse affect on physical performance and health (Caldwell et al., 1984; Kay and Marino, 2000) and more recently on cognitive functioning (Cian et al., 2001). These aspects are important when working; with a manual labourer, physical performance needs to be optimal to sustain the required work pace, and mental alertness needs to be maintained particularly when working with machinery. At the same time, office workers also need to maintain adequate cognitive functioning and hence fluid should be readily accessible to these workers to replace any losses. It has been identified that fluid losses as low as 2% can cause a decrease in performance (Haymes and Wells, 1986). This loss of body water has both circulatory and thermoregulatory consequences (Sawka, 1992). Core temperature eventually increases as the body attempts to diminish fluid losses by reducing sweating which increases the risk of heat illnesses. The more physically demanding a task, the greater the sweat losses and the more probable dehydration will occur. When combined with hot environmental conditions, this is exacerbated. Furthermore, some individuals sweat more than others when performing the same tasks emphasising the need to consider each individual when making fluid replacement recommendations. A very crude index of estimating fluid losses is weighing a worker before and after a shift when no fluid has been ingested. A rough guide suggests that every 1 kg decrease in body mass is equivalent to a loss of 1 L of fluid (Bean, 2002). Although theoretically an individual should replace all lost fluid, practically this may not be possible and could result in gastrointestinal discomfort and reduced work capacity. The Occupational Health and Safety Association (2002) recommends that workers be advised to drink approximately one cup of water every 15–20 minutes even if they are not thirsty. Workers are also encouraged to avoid alcohol and caffeinated drinks which act as diuretics. Bean (2002) recommends that fluid replacement be based on energy expenditure. If energy expenditure is 2000 kcal during the day, the worker should drink 2 L of water during the course of the activity, and if a worker expends up to 4000 kcal during a shift they should drink up to 4 L of water. With prolonged activity this fluid should include some carbohydrate to prevent the onset of hypoglycemia.

Bottom line:
Manual workers in South Africa should be encouraged to drink a little water regularly throughout the work shift. Therefore, fresh water sources should be made available at all worksites.

FIGURE 1.4
Useful hint for workers operating in hot environments. (From Christie, C.J., *Ergonomics Society of South Africa Newsletter,* July 2003.)

It has been encouraging to note the increase in IDC participants at IEA Congresses over the last decade, but this too must get more support from the IEA itself, not just the local organizers of the Congress. It is only by stimulating discussions between representatives from IACs and from IDCs that the minor commonalities and significant differences of the application of ergonomics in their respective areas can be understood and appropriately addressed. Only through such interactions can the magnitude of the problems faced in IDCs be fully apprehended.

Another positive development in the field of specific IDC research has been the increasing global input into the South American and South African Ergonomics journals.

It is evident that ergonomists working in industrially developing areas are making a tremendous effort to evaluate and improve the situation in their specific regions, but they need sustained interaction and backing from the international community of experts. The concept of "twinning" has regularly been put forward over the years and, where implemented with sensitivity to local conditions, has proved to be successful in isolated cases, and if this scheme were to be addressed more formally, under an initiative taken by the IEA in conjunction with IDC ergonomics societies, the benefits would be substantial.

1.5 Conclusion

Ergonomics is about people at work, and the vast majority of them work in IDCs. There is no doubt that ergonomics has done much to improve working conditions in the more affluent societies, but we are barely beginning to extend our efforts to include the huge biomass inhabiting IDCs. There is still a tremendous amount to be done in developing areas around the globe. One of the objectives of the IEA is "to improve the quality of life for all," yet we have failed to reach hundreds of millions of people who labor under horrendous conditions on a daily basis. The harsh realities so evident in IDCs must force a change in the priorities of the IEA: we need to minimize the ongoing exploitation and human suffering of these workers, many of whom labor as if slavery had never been abolished. Ergonomics can, and must, improve the situation, and it should be an accepted component of any national development strategy. The implementation of sound ergonomics principles could play a major role in assisting IDCs to achieve the sustainable development they are so desperately seeking. This would reduce the enormous cost in terms of worker abuse and occupational diseases and injuries, thus improving the quality of life of those concerned while at the same time there would be a notable increase in both the quality and quantity of production. The ultimate result must be a concomitant escalation in the economy of companies and nations. These countries, with so much potential, would then be capable of contributing to, rather than draining, the world economy. Ergonomics can play a key role in assisting developing areas to break out of their negative poverty-driven spiral. Indeed, ergonomics can be a major factor in narrowing the gap between the "rich" and the "poor" nations of the world.

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2

Human Factors and Ergonomics in Industrially Developing Countries: Necessity and Contribution

Klaus J. Zink

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2.1 Relevance of the Topic: The Responsibility to Act

The relevance of talking about human factors and ergonomics in relation to industrially developing countries (IDCs) can be described in several ways: there is a social or ethical responsibility for the working and living conditions of people in all countries on this planet in general. If anyone is not ready to accept this fact, he or she at least has to accept that our responsibility has been growing during the last several years, because of the growing globalization of economic activities (see UNCTAD 2007). Many people in Western countries enjoy low-priced goods made in developing countries often under bad working conditions (see http://www.chinalaborwatch.org). But even when buying goods at high prices, they are very likely to have been made in a developing country. While buying a quality shirt in Germany may cost more than EUR 125, its fabric mostly comes from Italy and the sewing

is done in Vietnam or China. The production costs are EUR 6 (Dobelmann 2007), but what are the salaries for the women sewing the shirts? How will this influence their working and living conditions?

If we are talking more and more about corporate social responsibility (see European Commission 2002) we definitely have to include all activities in the value-creating chain. In some industries, such as sportswear or sport shoe production, there have been some cases attracting a great deal of public interest (such as the Nike case for example; see Oxfam 2007). Recently China's toy industry attracted great interest because of the harmful materials used (WorldNet Daily 2007). But the discussion concentrated on the dangers for children playing with those toys; there was not much discussion about the people producing the toys, or their harmful working conditions (China Labor Watch 2007a). There are also bad working conditions in other industries like textile sweatshops (China Labor Watch 2007b). In the long run there may be some progress, because in some Western countries, like Germany for instance, product-testing institutions are no longer only interested in the quality of goods, they also want to get more information about the corporate social responsibility of the company selling products which have been produced totally or in part in economically developing countries. Although this is a first step, it is not preventing people from buying products which have been manufactured under poor working conditions and with low salaries for the employees, if they do not have the money to buy alternative products. Labor costs are only a very small part of the total costs or the price. If people in Western countries knew that a price (for instance an additional EUR 0.50) would create the chance for a higher salary and improve the living conditions of the manufacturing employees, some buyers would be willing to invest EUR 0.50 more, even if they could barely afford it. Of course this would have to be given to the employees, and should not increase the profit of the supplier. Therefore, the main problem lies in the lack of information available to purchasers.

How do we deal with this lack of information? Who should deal with this problem? Is this really related to human factors and ergonomics? What could we do as scientists to improve this situation? First the fact is that many more people are living in economically developing countries than in developed ones (see Population Reference Bureau 2007). And it will only be a question of time before international associations (such as the International Ergonomics Association) have more members from IDCs than from so-called industrially advanced countries (IACs). Also the globalization of economic activities will grow significantly. Therefore, it is definitely time to deal with these topics. As a precondition, we have to clarify our understanding of human factors and ergonomics, and we have to explain why and what this discipline could contribute to the solution of problems in IDCs—and to a better realization of globalization.

2.2 Human Factors and Ergonomics: A Broader Scope

The following is the International Ergonomics Association (IEA) definition:

> Ergonomics (or Human Factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall systems performance (IEA 2008a).

This quite broad definition focuses on human–system interface design, where these could be micro- and/or macrosystems. Talking about the work content, human–machine interfaces, and especially the working conditions, the micro- as well as the macrosystems can be of interest. In this context the concept of macroergonomics is of relevance, because macroergonomics is understood as a human–organization interface technology (Hendrick 2002). But in addition the concept of community ergonomics needs to be discussed.

Regarding the situation in IDCs all perspectives are relevant. But if we look at the lessons we learned in economically developed countries, then we first need an economic perspective, when discussing ergonomic interventions. For example we have to explain the relevance of ergonomics intervention for the future of the country and its economy. First of all the value of a healthy workforce needs to be demonstrated. This is obvious, if we look at countries in Africa with a high rate of HIV infections (see WHO 2007), but also if we analyze how in the past years industries (e.g., the textile industry) have shifted their production facility from one low-wage country to another with even lower wages (Mutume 2006). As productivity and motivation are based on a healthy workforce, IDCs need the introduction of systematic health management approaches including not only the work situation, but also the health situation within the family or the community. These are well-known approaches of the World Health Organization (see WHO 2008), which could be supported by local, but especially by international companies. If we want to retain markets in those parts of the world (instead of loosing them, when in other countries companies are producing at a cheaper price), we need to design work contents, which allow us to learn not only professional competencies, but also competencies for continuous improvement. Here the macroergonomics perspective can be seen as a key to connecting the concepts of personal and organizational development. Hence, economic developments are related to these approaches. For productivity improvements the introduction of usable technology is another important point to consider. But the macroergonomics concept of employee involvement and its approach of empowering people in the sense of developing more "democratic" structures are also of societal importance (Zink 2006). To summarize: not only in IACs but also in IDCs ergonomics has to be "sold." We have to prove that "good ergonomics is also good economics" (Hendrick 1996).

2.3 Working Conditions in IDCs: Globalization and Its Consequences

If we want to discuss the role of ergonomics and human factors in, and for IDCs, and the role which the so-called developed countries should play, we have to understand not only the specific working conditions in IDCs, but also the economic framework. The economic part of the discussion can be described by international trade agreements, by concepts of so-called foreign aid whose impact is so ineffectual, and by globalization. Trade agreements, which limit the export of goods produced in IDCs, and concepts of foreign aid, which partly contributed to the destruction of local markets, are better attributed to the responsibility of international politics. Therefore this chapter focuses on the effects of globalization. On the one hand, we can agree that globalization leads to positive effects, on the other hand we cannot deny its obvious negative effects on life and working conditions for some. To provide a better understanding of this statement, working conditions in

so-called Export Processing Zones (EPZs) shall be analyzed by way of example, in order to pose the question of responsibility for these conditions afterward.

The concept of EPZs is not a new one, for example the International Labor Organization (ILO) refers to EPZs in Spanish Barcelona and at the Western coast of Ireland, which were already founded in 1929 and 1959, respectively (see ILO 1998). But it was not until the 1970s that EPZs experienced a real boom. At this time, in the course of increasing globalization, industrial countries started to shift the labor-intensive steps of their production to low-wage countries—in particular Asia, Latin America, the Caribbean, and parts of Africa—in order to reduce their production costs (see ILO 1998).

> Globalization has caused the transfer of low-skilled manufacturing and processing jobs to less developed countries. This is one of the major factors that has led to the formation of numerous EPZs, a phenomenon that has developed largely in the face of globalization (Albracht 2005, p. 3)

Table 2.1 reviews this development over the last two decades. According to the ILO definition, EPZs can be seen as "industrial zones with special incentives set up to attract foreign investment in which imported materials undergo some degree of processing before being re-exported" (ILO 1998). To the respective target countries, direct (foreign) investments are an important contribution to attain national development goals; investments are supposed to increase a country's employment and export rates, to make a contribution to economic growth, to encourage the transfer of technologies and know-how, and to reduce the imports of those goods that are now produced within the country (Jauch 2002, Albracht 2005, International Confederation of Free Trade Unions (ICFTU) 2004, Singa Boyenge 2007).

Even though activities in EPZs still mainly focus on labor-intensive manufacturing processes, the spectrum of activities in EPZs has considerably widened over the years. In addition to traditional activities like textile and garment manufacturing, wood processing, leather stitching, toy and electronics manufacturing, financial, high technology, logistics, and even tourist centers are increasingly integrated in EPZs (ICFTU 2004, Gresh et al. 2006). Given the diverse characteristics of EPZs, within its "Special action program on social and labor issues in export processing zones," the ILO developed a working definition of EPZs according to which EPZs may be understood as "any situation in which an incentive is offered to investors, and that investment is primarily for export" (ILO 1998). The real benefits of EPZs for a country are controversial and widely discussed.

TABLE 2.1

Estimates of the Development of EPZs

Years	1975	1986	1997	2002	2006
Number of countries with EPZs	25	47	93	116	130
Number of EPZs or similar types of zones	79	176	845	3000	3500
Employment (millions)	N/A	N/A	22.5	43	66
Of which China	N/A	N/A	18	30	40
Of which other countries with figures available	0.8	1.9	4.5	13	26

Source: Singa Boyenge, J.P., ILO database on export processing zones (revised). Sectoral Activities Programme. Working paper no. 251. International Labour Office, Geneva, 2007.

For instance, according to the ICFTU, the transfer of technologies and know-how between the zones and domestic enterprises is often limited, as production within the zones mainly requires low-tech and low-skill. Furthermore, the material needed by the companies is often imported, instead of being bought from the local markets of the respective country. As relocating is relatively easy for the companies set up in the zones, investments tend to be of a short-term character. In the end, the net foreign exchange earnings are often low and may not even cover a country's investment in the EPZ or the concessions awarded to investors (see ICFTU 2004).

Other contested points are labor standards, labor relations, and the health and security of workers within the zones (Jauch 2002, Albracht 2005, ICFTU 2005, Singa Boyenge 2007). Particularly for industries, such as textiles, garments, and electronics, which are exposed to short product life cycles and strong competition, business success is often achieved by the exploitation of cheap and compliant workers, and the violation of labor and social laws (ICFTU 2004, Schipper and de Haan 2005). This situation is mainly provoked by multinational companies, which expose their production to international competition, in order to increase sales. Differences between the EPZs with regard to productivity (achieved for instance by overtime work), wage levels, working conditions, and environmental safeguards, consequently allow multinational enterprises to choose the most adequate production location in order to improve the return on investment (Gresh et al. 2006). As seen in the case of the textiles and garments industry, commercial enterprises consequently choose among the cheapest suppliers and sometimes even play them off against each other in order to minimize production costs. In this context, the closedown and outsourcing of factories are reported to be used as leverage (ICFTU 2005). Given these methods of multinational enterprises and the big offer of potential production locations providing cheap labor forces and favorable general conditions (see Table 2.1), target countries of foreign investment are exposed to harsh competition (Gopalakrisnan 2007, Gresh et al. 2006). Consequently, many countries' governments try to dispute their position on the global markets by implementing duty-free imports and exports and tax concessions, as well as providing infrastructure and a cheap workforce within the EPZs. Likewise low or missing social standards and environmental safeguards as well as the disregard of basic labor rights are used as competitive advantages in order to attract (mainly foreign) investors (ICFTU 2004, Gresh et al. 2006, Singa Boyenge 2007).

2.4 Working Conditions in Export Processing Zones: Some Examples

In connection with these issues, the ICFTU (2004) refers to the fact that in a multitude of cases weaker basic legal conditions reflect the factual legal situation of a country. Nevertheless, in EPZs one can indeed detect a more casual management of working conditions than in the other regions of the country concerned (ICFTU 2004). First, this might be because sometimes EPZs are explicitly excluded from the national legislation. Second, in some countries with EPZs the effective implementation of national laws is only rarely enforced; examinations are cursorily executed and frequently the national legal system suffers from a lack of resources for enforcement. Last but not least, the access of labor unions to EPZs is often refused, so that any chance for the creation of a strong labor union is extremely limited. This leads to violations of employment rights and to an exploitation of labor in EPZs without any

fear of consequences (ICFTU 2004). Hence, the harsh international competition is carried out at the expense of the employees in the EPZs (ICFTU 2005, Albracht 2005).

> In a highly globalized industry, the companies offer the consumers a customized product in as little time as possible. Suppliers are expected to react to changing demands on a day-by-day basis. As a consequence, the workforce in these factories is expected to be as flexible as needed (Schipper and de Haan 2005, p. 67)

Due to the limited availability of detailed data, drawing an all-embracing picture of social protection and working conditions in EPZs is difficult. However several references indicate unacceptable working conditions and the disregard of national legislature (ICFTU 2005, Gopalakrisnan 2007). In many EPZs workers are exposed to strong pressure in order to meet the buyer's high requirements in regard to delivery times, flexibility, and production costs (Jauch 2002, Albracht 2005, Schipper and de Haan 2005). Wages in EPZs indeed are often higher than comparable wages outside the zones, but frequently these wages can only be achieved by the production of higher quantities and extended hours of work (Jauch 2002, Albracht 2005). In other cases workers are forced to fulfill extensive and unpaid overtime by the threat of fines, held back wages or loosing a monetary deposit (ICFTU 2004). Furthermore, the sometimes required accommodation for the workers in dormitories on the factory site is characterized by limited mobility and often unacceptable, unsanitary conditions (Albracht 2005). There are also repeated reports of sexual harassment and discrimination against female workers, who form the majority of the workforce in EPZs, especially in labor-intensive industries such as textiles, garments, and electronics. In comparison to their male colleagues, women in EPZs are often paid worse and have less access to further education (ICFTU 2004). The Catholic Agency for Overseas Development (CAFOD) also refers to cases where pregnancies and marriages are prevented by the employer by threatening sanctions in the form of job loss or the exclusion from advanced training (CAFOD 2004). Furthermore, case studies show shortcomings in measures of occupational health and safety. Cases are repeatedly reported where workers were not provided with protective clothing or where protective clothing was inadequate. Similarly, workers were not trained in how to handle hazardous substances or situations, e.g., fires (CAFOD 2004, ICFTU 2004). The production of information and communication technology is particularly associated with high health risks, because many of the components used contain hazardous substances and heavy metals (CAFOD 2004, Schipper and de Haan 2005).

A study of working conditions in Chinese EPZs carried out by CAFOD showed that some of the workers were exposed to hazardous chemicals and vapors without being provided with appropriate protection or training. The workers affected knew neither the names of the chemicals they had to deal with nor whether they were dangerous or what protection they should use. As a consequence, the workers' skin was in constant contact with chemical substances. Vapors and dusts that occurred when soldering and grinding were inhaled without being filtered because no protective masks were available. Chemicals were delivered in unlabeled containers and stored improperly. Shifts of up to 11 h working at test screens or on microscopes, such as with the installation of single components, lead to eye problems. Extended working hours on the assembly line resulted in cramping of muscles and pains in the legs, shoulders, and back. Insufficient hearing protection was provided for work with loud presses (CAFOD 2004). That such working conditions can also lead to accidents is shown in a case study of Chinese EPZs carried out by Pareles (2005).

As already mentioned freedom of assembly and the ability to bargain are heavily limited in some EPZs. Furthermore, labor unions are often denied access to these zones.

By threatening dismissal or the shutdown of the factory, or even violence and death, employers try to control their employees and hinder them from striking, collective bargaining, or protesting (ICFTU 2004, Schipper and de Haan 2005, Gopalakrisnan 2007). Hence, employees within the zones lack the ways and means to stand up for improvements of their working conditions (Schipper and de Haan 2005). These authors cite the production of hardware for information and communication technology as an example of an industry which is notorious for its lack of labor unions. In particular, in Asian countries, labor unions in EPZs are often forbidden, or their access to the zones is heavily complicated. For instance, on the one hand the Philippine government officially grants the workers in the zones the right to unionize, referring to diverse penalties for those enterprises which do not issue this right. On the other hand workers in the zones are actively deterred from forming labor unions, and the contact of labor unions with employees within the zones is cut off by fences and armed supervisors around the production facility (Schipper and de Haan 2005). Also, in Mexico, workers are prevented from standing up for the improvement of their working conditions. For instance, Mexican workers reported threats of dismissal or black listing, making it impossible for fired workers to find new employment (Schipper and de Haan 2005). In China, the only legal union is the state-controlled All China Federation of Trade Unions (ACFTU), even though it is not recognized by international labor union federations. The absence of effective unions or collective action of other kinds makes it difficult for Chinese workers to assert their legal rights and to stand up for sustainable improvement of their working conditions, also in EPZs. Furthermore, many of the workers do not even know their official rights, because there is no relevant information such as labor unions would provide (CAFOD 2004).

Are we concerned by these situations as individuals? Are we buying goods produced under these circumstances? As scientists, do we talk about these problems in our lecture halls or at conferences? We work together with companies in Western countries that are at the end of the supply chains. Again: do we talk or ask them about the working conditions in their whole supply chain and what they could and should do to improve working conditions (and therefore living conditions)?

2.5 Possible Contributions of the (Western) Human Factors Community

Globalization is not only a problem for IDCs, but has also a strong influence in IACs. The international competition and the idea of permanently increasing the shareholder value of big companies are leading to concepts of cost reduction. Many of these concepts have the prefix "lean." Similarly many ergonomics departments have become "lean" during the last few years, because ergonomics has also been related with costs. Therefore, worldwide the huge potential of ergonomics has to be sold, because human factors/ergonomics seems to have a specific image which is often not a positive one: The necessity to "invest" in ergonomics is mostly seen in relation to worker protection laws, which bear the costs and only lead to benefits for employees. This could not be further from the truth, but we as ergonomists need to promote a more constructive, beneficial image.

First of all the potential of this applied science has to be discussed, together with some of the results that can be gained; then the benefits for management and society as a whole will be shown (Zink 2006).

2.5.1 Precondition: Human Factors and Ergonomics—Necessity for a Paradigm Shift

The above-cited definition of ergonomics/human factors shows that this discipline is based on a holistic approach bringing together not only different disciplines, but it also has different targets such as humanity, economy, and ecology (Zink 1999). This holistic approach is the unique characteristic of ergonomics compared to other sciences such as psychology or physiology which deal with a specific aspect of the problem. Insofar as the core competencies required by an ergonomist are very broad, they also include the economic evaluation of work done (IEA 2001). This asset of ergonomics is often not realized in practice. Therefore, the "marketing" of ergonomics itself needs a paradigm shift. We have to explain that ergonomics has a positive mission, instead of saying we have to do it because of laws, and in most cases it is related to a huge amount of costs and the benefits are "only" for employees. If we only relate ergonomics to laws for the protection of employees, then it might seem to be only a cost factor. If we use the whole potential, we can create win–win–win situations: Restructuring the organization in a more process-oriented way renders it is possible to become more customer-oriented. Work division along the key processes leads to the possibility of creating a holistic work content for individual workers, and indeed for teams of workers. This again leads, as experience shows, to more satisfaction and more motivation. The result is normally an increase in productivity and higher customer and employee satisfaction. In this sense good ergonomics is good economics.

Developments in recent years in the United States and in Europe have created a new necessity to deal with human factors. More and more societies and citizens express a critical view of big business which focuses only on shareholder value maximization. Therefore, we see several activities to (re)install "corporate social responsibility." Besides the activities of international organizations like UNO and OECD, the European Union published a Green Book describing the contents of such an approach in 2001, followed by a strategy in July 2002 (European Commission 2001, 2002). All these approaches focus on sustainability based on the economical, social and ecological performance of enterprises. Ergonomics could play an important part within these strategies because of its holistic and preventive character—and this in turn would again contribute to a positive image.

Ergonomics, in the past and present, has been the task of specialists. To make a real breakthrough it has to become a management topic. This could be realized in using the same approaches or management systems as are used for (total) quality management and performance measurement. A notable entrance in this context is to refer to international excellence models like the Excellence Model of the European Foundation for Quality Management (European Foundation for Quality Management 1999–2003), the Australian Business Excellence Framework (SAI GLOBAL 2007) or the U.S. Malcolm Baldrige Performance Excellence Criteria (United States Department of Commerce 2007). All of them are highly recognized by management in using their "language" and bringing topics like human factors to the top management level. We used this concept, with minor modifications, to bring the health topic to management level. This gave enterprises the chance to use the same approaches for (total) quality, environment, and health promotion in building up respective, but integrated management systems. Besides countable economic results, we also found positive changes in corporate culture regarding leadership and people involvement (Zink and Thul 2006).

2.5.2 Human Factors/Ergonomics and Management

The difference between companies is mainly people, as technology and organizational structures may be imitated. The qualification and motivation of a work force is hard to imitate,

therefore, human resources are the most relevant enabler for the success of a company/organization. Jeffrey Pfeffer, professor of organizational behavior at Stanford University, United States, studied the sources of companies with the best results in the Unite States. His summary was "Building profits by putting people first." One of his explanations reads as follows: "Success comes from delivering value to your customers, and the ability to deliver value comes from having sound conceptions of what customers want and value, and how to organize and manage people to produce that value" (Pfeffer 1998). How to organize and manage people is also a topic of human factors as part of corporate social responsibility. The above quotes demonstrate the interrelations between people-based strategies and sustained profitability.

But there is another explanation why ergonomics is a precondition for customer satisfaction. As we know, global competition is mainly based on quality and price. As standards and products are becoming more and more uniform, we need additional sources for differentiation. An ergonomically designed product, in the sense of accessibility, usability, health protection, and so on could be the feature for differentiation and customer satisfaction. If we accept that ergonomics takes a holistic approach, the product could be designed to fulfill these features, but it may also be designed in such a way that it could be produced in an economic, ecological, and ergonomic way. A module structure of the product could deliver the possibility for an assembly based on holistic work contents for a single person or a team, but also take into regard inspection, repair or disassembly task from a life-cycle perspective (Zink and Eberhard 2006). An additional advantage for competition could be the connection between ergonomics and ecology regarding the whole life cycle of the product. Summing up by repeating: management should invest in ergonomics, because "good ergonomics is good economics." As a consequence these are the tasks to fulfill by management (as a first approach):

- Investment in human factors/ergonomics
- Restructuring of the product development processes
- Use of integrative management systems and excellence models
- Creation of win–win–win situations
- People involvement in improvement activities

The last recommendation is very much related to macroergonomics and is commonly known as participatory ergonomics. Participatory ergonomics includes all approaches with employee involvement. Some of them have the character of problem-solving groups, also known as quality circles. The idea is that employees know much more about their work situation than external experts or management. Therefore, use your employees as consultants. They know more and are much cheaper than consultants. Another relevant effect of such an approach is that solutions created by employees have a much better acceptance than those decided by management without consulting the respective employees. And there is a last effect concerning society—mature employees are also mature citizens.

2.6 Human Factors/Ergonomics and Society

The relation between ergonomics and society is at least twofold:

The fact which is most obvious is that society has to bear the consequences when companies do not invest, or do not invest enough, in occupational health and safety. The

resultant early retirements, with all the financial consequences for the social systems of a society, are to be discussed. The same applies to work-related injuries caused by accidents, or in the worst case the number of work-related fatal injuries. The fact that we have made some immense improvements in these incidence rates in Western countries is very much related to the application of ergonomics. To reduce work-related accidents is surely also a question of social responsibility. But accidents are not only caused by work. We also have to consider road safety, air traffic safety, nuclear power plant safety and so on. In all fields, ergonomically designed interfaces are able to reduce the number of "misfits."

However, as described in the beginning of this chapter, the uniqueness of ergonomics can be described by its holistic approach, also known as sociotechnical systems theory. Such approaches are also valuable in solving inner-city problems, as shown by our colleagues in Madison, Wisconsin, in "inventing" community ergonomics (Smith et al. 1994). Also mentioned before, "participatory ergonomics" as an element of a learning organization will lead to mature employees, which in turn means mature citizens for the society. Recognizing the importance of ergonomics to the society would lead to the following tasks for the politics:

- Integration of ergonomics in educational programs
- Support of universities in establishing departments for human factors/ergonomics
- Support of research in this field
- Using international networks like IEA or ILO

2.6.1 Creating a Quality Label

The International Ergonomics Society (IEA) has started an activity named Ergonomics Quality in Design (EQUID) which at first focused on the ergonomic design quality of products. This initiative could be expanded regarding the quality of workplaces or work-systems design. Companies which include EPZs in their supply chain could ask their supplier to apply for such a quality label to be sure that at least ILO or OECD standards are met.

2.6.2 Intensifying the Institutional, Personal, and Methodological Support

National Human Factors or Ergonomics Societies should become more international. As discussed and initiated in the Executive Committee of the International Ergonomics Association at a Council Meeting in Florence in 2001, we need a more intensive cooperation between Federated Societies in Western countries and (emerging) groups and societies in IDCs (twinning), which has only been realized in part (see IEA 2002). But also an increased personal engagement by active or retired ergonomists (as shown by people like Kogi, Wiesner, Shavanaz, and some others), but also by a recent joint project of the IEA and the Foundation for Professional Ergonomics (USA) to assist ergonomists in IDCs (see IEA 2008b).

Beside these activities on a national and international level we should continue to develop instruments and methods usable in those countries on an international level, like the "ergonomic checkpoints" (developed by IEA and ILO), or low-cost and participatory intervention concepts like those shown by Scott and Kogi, with very successful

results (Scott 2008, Kogi 2008). In this sense, the initiative of Pat Scott in editing this book is another very important contribution.

2.6.3 Educating Consumers: Improving Working Conditions by Responsible Shopping

As we have seen in describing working conditions in the so-called EPZs there are losers and winners: The losers are the people gaining a little bit more money than others by accepting bad working conditions. The winners are the companies (mostly at the end of the value-added chain), and also the consumers in Western countries (not knowing how their cheap products have been made). Realizing this fact we need, at least, two activities:

We should support those nongovernmental organizations (NGOs), which are fighting for better working and living conditions by using our opportunities to inform as many people as possible about this situation. As seen in the recent case of toxic toys from China, the most important and powerful target group are the (future) consumers in Western countries. Maybe we need some sort of "Consumer (Economics and) Ergonomics" educational programs starting in the schools, explaining the relationship between prices and working conditions in service and production. There is also a lack of education at a university level. The message we should therefore be trying to get across is: "Improving working conditions by responsible shopping." As consumers, but also as citizens, we should demand "corporate social responsibility" from those profiting from ignominious working conditions in the supply chain. There are a lot of rules of the ILO or the OECD concerning globalization and working conditions, so we do not need new ones. We need the acceptance of existing rules throughout the supply chain. As we now have a competition of supply chains we may also need a competition of "Supply Chain Ergonomics."

2.7 Summary

Many people in Western countries may not realize that the greater part of the population on this globe is living in IDCs. The improvement of working and living conditions by ergonomics interventions is mainly focused on a national perspective. Though Human Factors and Ergonomics Societies (and their members) are not able to solve international political challenges, they can contribute toward improving the situation. The first and main task is to improve the image (and marketing) of our discipline. We should show how we can contribute to corporate social responsibility and better economic results at the same time. We should also support NGOs in their efforts to inform customers under which circumstances the products they buy have been produced. But we should also spread this message ourselves, wherever our place within society may be. The earlier we start the better.

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3

Ergonomics, Safety, and Health in Industrially Developing Countries: A Needed Multilevel Interdisciplinary Approach

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3.1 Introduction

We live in a world where numerous societies face inhumane working conditions. People are being treated with rudeness and disrespect, making the concept of "decent jobs" have no meaning at all (ILO, 2001). During the last decades, the majority of the world's working population has been confronting the lack of adequate and satisfactory work systems. Taking part in such a fragile working environment constitutes one of the major causes for workers to become frustrated and dissatisfied, with consequences of low productivity levels, poor product/process quality, and poor quality of working life (QWL). This is a discouraging reality considering that work, as a human activity, "constitutes one of the ends of the economic system and a basic need for man in order to give meaning and content to his/her life" (Hofstede, 1982). In this chapter we discuss how the scientific discipline of ergonomics (human factors) and the occupational safety and health (OSH) field jointly contribute to the improvement of the QWL at various levels (a multilevel approach) and most importantly, attempt to illustrate the needed "symbiotic" relationship (close and often long-term interactions between two bodies) between the two of them within the context of industrially developing countries (IDCs).

3.1.1 Ergonomics, Safety and Health, and the Quality of Working Life

As described by Clerc (1985), "Work concerns man as a whole: not just muscle and nerves, but intelligence, capabilities, feelings and aspirations." Improving the conditions of work needs to incorporate all dimensions of the worker, in addition to the socioeconomic and

cultural context. In IDCs, work is the only source of economic support for family and relatives, and constitutes an integral part of family and social life. Undoubtedly any direct or indirect effect of work on physical and mental health will have an impact not only on the workers themselves but also on their families and on society as a whole (Clerc, 1985; Waluyo et al., 1996). Furthermore, the World Health Organization (WHO) sequentially links *Work, Health, and Development* where healthy workers lead to productive workers and in turn to successful businesses. These businesses generate a healthy economy which in turn will promote sustainable development. The WHO states that a "healthy workplace promotes a good quality working environment which fosters support, trust, respect and dignity" (Kortum, 2008).

Ergonomics is the scientific study of people at work considering human capabilities and limitations and the design of work so that it fits the workers' needs (Stubbs, 2000). Thus ergonomics combines science and engineering with a thorough understanding of human capabilities and limitations. Helander (1999) claims that ergonomics is "a compassionate, humanistic approach, which produces high quality design with high benefit/cost, greater productivity, greater user satisfaction and a reduction of injuries." OSH aims at preventing fatalities and disabling injuries and diseases that result from work-related events. Although it is commonly related to workplace accident reduction, a lack of injuries does not necessarily mean working in a safe and healthy environment. Safety is more than merely a "noninjury" situation. It needs to be considered proactively, with a systemic approach that goes beyond injury prevention (WHO, 1995; Brunette, 2005).

Ergonomics, as a scientific discipline, and the field of OSH interact and share the same goals regarding the *overall well-being of the worker* and the improvement of the conditions of work. Shahnavaz (1996) reminded us that IDCs are where ergonomics has yet to make its presence felt in practice. More than 10 years later we still claim that workers in IDCs desperately need workplace interventions that simultaneously apply principles of ergonomics and OSH to improve overall well-being, productivity, and quality via a collaborative and multidisciplinary approach. Successful interventions that have the ability to go beyond the work environment to include local communities and rural villages can indeed build local networks for sustainability (Jafry and O'Neill, 2000; Arcury et al., 2001; Kawakami and Kogi, 2005). Without doubt such efforts will lead to the reduction of occupational health disparities, the alleviation of poverty, and the development of the IDC (Zalk, 2001; O'Neill, 2005; Thatcher, 2005).

Considering that ergonomics in the workplace has to do largely with the safety of employees, both long- and short-term (Wikipedia, 2008), the need to build ergonomics into the OSH field becomes urgent. There is growing evidence of the relationship of ergonomics, safety factors, and injury rates in IDCs (Brunette, 2003a; Ibarra, 2003; Shikdar and Sawaqed, 2004) but more studies and interventions need to be replicated. IDCs need to take advantage of ergonomics principles and methods; apply them in their design of systems, environments, machines and tools, and incorporate them into their activities focused on the continuous improvement of safety and health at work. Fortunately, ergonomics draws on many disciplines in its study of humans and their environments, including anthropometry, biomechanics, mechanical engineering, industrial engineering, industrial design, kinesiology, physiology, and psychology which "facilitates" its inclusion into OSH activities at the individual, organizational, and community levels (Helander, 1999). Table 3.1 presents several dimensions (C1) of ergonomic research activities in various IDCs, and proposes some mechanisms (C3) by which the domains of occupational safety and health and ergonomics (OSHE) interact to impact on worker's well-being and health. Note that

TABLE 3.1

Ergonomics and OSH Exchange in IDCs

C1: Ergonomic Aspect (IDCs)	C2: Scope of Projects	C3: Ergonomics and OSH Exchange
Anthropometry and human variability (Sri Lanka, Vietnam, Indonesia, Egypt, India, Hong Kong)	•Comparative study of body size variability between people in the United Kingdom, Sri Lanka, and Vietnam •Anthropometric measurement methods •Anthropometric data collection and analysis •Anthropometric differences and design	•Reduction of job hazards (e.g., materials handling) due to improved design •Increase in worker's well-being (lower physical discomfort) •Stronger management commitment in OSHE
Education and training (Zimbabwe, Philippines, India)	•Education and training in ergonomics •Development of ergonomics training and research	•Reduction of job hazards (e.g., mechanical, fall hazards) •Worker' awareness of impact of stress, fatigue, poor design, etc. •Stronger management commitment in OSHE
Working conditions and industrial ergonomics (Argentina, Mexico, Peru, Malaysia, China, Philippines, Vietnam, Iran, Indonesia)	•Ergonomics in industry and strategies for improving working conditions and worker's health and satisfaction and productivity •Ergonomic research in labor protection •A university approach for promoting ergonomics and working conditions •Macroergonomics research in production and assembling departments •Ergonomic influence of shift-work •Ergonomics, health and safety in small and medium companies	•Reduction of job hazards (e.g., materials handling, mechanical, confined spaces, falls and electrical hazards, psychosocial stress, workplace violence) •Worker' awareness of impact of conditions of work on health •Stronger management commitment in OSHE
Occupational biomechanics and WRMSDs (India, Indonesia)	•Electromyography (EMG) signals in sitting work postures •Low back pain problems in lifting and carrying •Effects of corrected work posture on productivity	•Reduction of job hazards (e.g., materials handling, psychosocial stress) •Worker' awareness of impact of awkward postures on back pain •Stronger management commitment in OSHE
Organizational and cultural aspects (Brazil, various Latin-American countries)	•Organizational environment as a source of stress: an ergonomic view •Cultural aspects in learning organizations design •Development of an organizational climate instrument for Latin-American countries	•Reduction of job hazards (e.g., psychosocial stress, fall hazards, lack of organizational support) •Increase in worker's well-being (e.g., higher morale, satisfaction) •Stronger management commitment in OSHE

(*continued*)

TABLE 3.1 (continued)

Ergonomics and OSH Exchange in IDCs

C1: Ergonomic Aspect (IDCs)	C2: Scope of Projects	C3: Ergonomics and OSH Exchange
Physical environment (Brazil, Indonesia, Malaysia)	•Thermal comfort zone for tropical regions •Performance characteristics during exercise at different ambient temperatures •Investigation of the potential for enhancing work productivity by acclimatization to hot-humid environments •Effects of illumination on productivity •Heat stress in a railway workshop	•Reduction of job hazards (e.g., materials handling hazards, confined spaces, heat stress, poor illumination, psychosocial stress) •Increase in worker's well-being (lower physical discomfort, stress, and fatigue) •Stronger management commitment in OSHE
Product/tools/equipment design (Hong Kong, India, Indonesia, Nepal, Sri Lanka)	•Bus cab design for Cantonese drivers •Ergonomic design of low-cost personal protective equipment •Ergonomic aspects of personal protective devices in Sri Lanka •Role of ergonomics in planning new tanker construction •Design of control rooms •Improvement of productivity through changes in workbenches •Ergonomic considerations in the design and operation of solar heaters in Nepal	•Reduction of job hazards (e.g., materials handling hazards, toxic and chemical exposure, psychosocial stress) •Worker' awareness of "fit to the worker" design approach •Stronger management commitment in OSHE
Occupational health and safety (Indonesia, Malaysia, South Africa, Thailand, Venezuela)	•Development of ergonomics in occupational health services and work productivity •Ergonomics for the improvement of health and safety of female workers in industrially developing countries Thailand and Japan •Facing OSH challenges •Development of occupational hygiene	•Reduction of job hazards (e.g., toxic and chemical exposure, psychosocial stress) •Worker' awareness of impact of conditions of work on health •Stronger management commitment in OSHE

Source: International Labor Organization, *Ergonomics in Developing Countries: An International Symposium*, ILO, Geneva, Switzerland, 1987; Brunette, M.J., Working conditions in Peru: A survey study of worker's perceptions in an industrially developing country, University of Wisconsin-Madison, Industrial Engineering Department, Madison, WI, Publication No. 30-72784, Dissertation Abstracts International, 63(11B), 2003b.

all the suggested exchanges include stronger management commitment to OSHE. The role of decision makers is vital in the implementation and sustainability of OSHE programs in any type of organization.

There are some common myths about ergonomics which might have affected the field action for this discipline in both the developed and the developing world. Ergonomics is frequently related solely to physical aspects at the workplace and the prevention of work-related musculoskeletal disorders (MSDs). This view has created confusion about what ergonomics is and its application. For example, people think that ergonomics provides proper design of chairs or that it teaches how to maintain proper postures in the office environment in order to minimize back pain. Undoubtedly chair design is not very representative for the wide range of activities of the ergonomics discipline (Helander, 1999). Moreover, the term itself (ergonomics) is neither widespread nor well understood by the majority of the IDCs professionals in the various related fields including engineering, public health, and social sciences. This lack of understanding is a present barrier to any attempt to diffuse the use of ergonomics among health and safety professionals in IDCs and to facilitate potential collaborations with ergonomists.

3.1.2 Ergonomics and Its Multilevel Nature

The *multilevel nature* of the ergonomics discipline is frequently ignored. By multilevel we refer to a three-level approach of evaluating a safe and healthy workplace. Such an approach evolves from the microapproach (single factor within the work system) to the macro- or systemic approach (multiple factors interacting within the work system) ending with the extra-organizational view of the work system (social, political, and economic factors). Figure 3.1 illustrates this multilevel approach that includes the micro-, the work system,

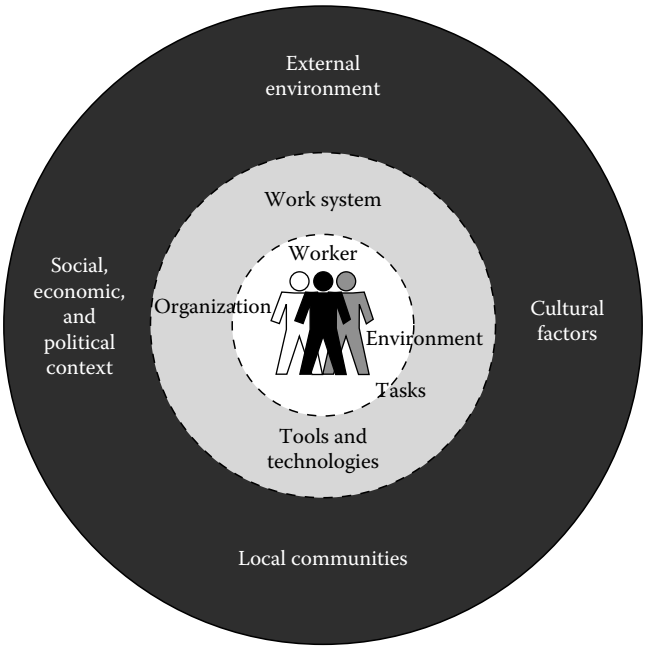

FIGURE 3.1
Ergonomics and OSH evaluation: A multilevel approach.

and the external or extra-organizational levels of analysis. The "microlevel" approach to ergonomics refers to the simple analyses with only one element of the work system being evaluated. For example, a better chair design (one element) or an improved tool design (one element) is related to an improved situation such as a decrease in workers' back pain or a reduction in workers' hand discomfort. A broader perspective to work-related problems needs to adopt a "systemic" view and to assess the work system in terms of its five main components: tasks, tools and technologies, physical environment, organization, and the person.

This holistic approach to better understanding of the work system (balance theory) proposed by Smith and Carayon (1989) is used to analyze different elements of the work system, their interrelations, and outcomes. Each one of these five factors has specific characteristics that can influence exposure to hazards and injury potential. The "balance theory" states that an element in the system will influence any other element, originating a continuous interplay among elements (systems balance principle). At the same time, interactive effects from the various elements can cause or mitigate exposures, so "positive" aspects of the system could compensate for "negative" aspects (compensatory balance principle). For example, having a good relationship with one's supervisor, considered as a positive element in the system, could be used to overcome some adverse aspects perceived by workers, such as inflexible working schedules. These two elements are known factors which affect safety and health outcomes such as injuries and near misses. An assessment of the various elements of the work system and their relationships with injuries and accidents in an IDC (Mexico) is presented in Box 3.1.

In addition, our ergonomic eyes need to look outside the work system (external environment). Not only the internal elements of the work system need to be analyzed but also the larger context in which the worker lives, extra-organizational factors including socioeconomic and cultural factors (e.g., macroergonomics, community ergonomics, cultural ergonomics). In either developed or developing societies, cultural, socioeconomic, and work system factors are interrelated and play a key role in the overall well-being of the entire working population (Clerc, 1985). Moreover, in IDCs, work and workplace are the major sources of the well-being of the individual and of the developing society (Bruton and Fairris, 1999). Cultural factors relate to the genuine nature of personality, behaviors, beliefs, stereotypes, traditions, lifestyle, and the like, that characterize a group of people. Economic factors are those factors related to economic status at the individual, organizational and country level; income levels, GNPs and the like. Social factors are those factors associated with the living conditions and social status of a group of individuals; ethnic background, education level, occupation, living conditions such as housing and sanitation services, infrastructure and class/social structure. Political factors include existing policies and regulations and the way they are enforced. In IDCs, the status of their economic, educational, and social environment drastically affects the work system that workers confront on a daily basis. Inclusion of these factors in the evaluation of safe and healthy human work is mandatory within IDCs in which workers live and work. An example of how external factors were included in a large ergonomics, safety and health and working conditions survey study in an IDC (Peru) is presented in Box 3.2.

3.1.3 Symbiotic Role of Ergonomists and Safety Professionals in Improving Workers' Health

In today's global economy the promotion of healthier, safer, and sustainable workplaces is a major challenge which professionals face when trying to improve the quality of life

BOX 3.1 ERGONOMICS AND OH&S IN MEXICAN ENTERPRISES: A CASE STUDY

Even though Mexico is close to the United States which has strong occupational health and safety and ergonomics regulations, the situation in Mexican companies is very different. Having had the experience of working in different manufacturing industries in Mexico, it has been possible to recognize the precarious state of occupational health and safety in Mexico. Because there are not specific regulations and procedures to register statistics regarding ergonomic conditions, it is almost impossible to estimate the magnitude of the various health, safety, and ergonomically related problems among workers in Mexican industries. Ergonomics is a relatively new topic in Mexico and it has been focused mainly on product design rather than the entire workplace. With few regulations, bureaucracy and corruption, there has been a lack of interest in the employees' health and welfare for many years. Health and safety at work is a new topic for managers. Because of the economic situation and pressures, company's objectives are focused on productivity exclusively. Industrial workers work long shifts with no break apart from one to have their meal. Because there are not many jobs, workers fear to complain about excessive work loads, long working hours, or earning very low wages.

In order to investigate the situation in the Mexican manufacturing industry, a study was conducted to assess how psychosocial factors (i.e., motivation, communication, job satisfaction, etc.) related to the development of overall health, mental distress, and work-related upper limb disorders within manual assembly operations in Mexico. Results of this study showed a clear correlation between the working environment and psychosocial factors as well as injuries and accidents. Not only the physical characteristics within the work environment such as tools, assembly lines, and machinery design have an impact on the development of musculoskeletal injuries, but it was also found that the way in which work has been organized played a key role. Work design and organization involved many important issues such as training, environment, health, safety, welfare, communications, etc. It was concluded that the appropriate integration of all these factors affected the way in which employees feel at work. It becomes critical to acknowledge the relationship between the individual and the work environment and to place emphasis on the need for a holistic ergonomics approach in the workplace (Luczak et al., 1998; Eklund, 1999).

The health and safety professional has a big challenge in helping enterprises in IDCs to better understand that looking holistically at the ergonomics approach is a key factor for QWL assurance and total quality management philosophies implementation. This approach could help companies to increase productivity and competitiveness in a global market.

Source: Ibarra, T., *Contemporary Ergonomics*, Taylor & Francis, UK, 2003.

at the individual, organizational, and community levels. Engineers and public health and safety professionals need to take leadership in the improvement of working conditions by becoming knowledgeable on the various applications of the ergonomics discipline. Such collaborative approaches are sorely needed to reduce health disparities between and within industrially advanced countries (IACs) and IDCs. As reported by Shahnavaz (1987),

BOX 3.2 QUALITY OF WORKING LIFE IN PERU: A SYSTEMS APPROACH

"Working conditions in Peru" is a pioneering study that focuses on understanding how different elements of the work system as well as socioeconomic factors influence workers' satisfaction and health in an IDC. Primary (dependent) variables were worker satisfaction and health-related variables. Health-related variables included overall health status, musculoskeletal and mental distress symptoms. Secondary (independent) variables such as working hours and salary, physical environment and ergonomics, OSH, work-related welfare facilities, work discrimination, psychological job demands, and organizational factors were examined. Elements outside the work system, such as socioeconomic factors, were also considered in the analysis. The data collection tool was a working conditions questionnaire survey written originally in English and translated into Spanish. The study participants consisted of 12 manufacturing companies from the private sector. Collecting the data took place in Lima, Peru in March 2002. There were a total of 1373 completed questionnaires, a 78.5% return rate of the invited participants.

Findings of this study suggest the potential impact of factors such as having a good fit between the working hours and the family/social commitments, psychological job demands, having an interesting job, and adequacy of household income on worker's well-being. In addition, inclusion of extra-organizational factors contributed to a better understanding of worker's job satisfaction and health. It was found that a significant percentage of Peruvian workers face problems away from work that might affect their mental and physical health. These include inadequate sanitary living conditions, access to safe water, and inadequate transportation systems. When these issues are added to poor conditions of work, as found in this study—long working hours, poor physical environment and a lack of ergonomics, plus unsafe workplaces—greater levels of musculoskeletal distress and mental stress, and lower levels of perceived health and job satisfaction are reported by the workers.

Source: Brunette, M.J., Job satisfaction and occupational health in Peru: A survey study of worker's perceptions in an industrially developing country, *Proceedings of the 2003 International Ergonomics Association Congress*, Seoul, Korea, 2003c.

common OSH factors in IDCs, such as their high rate of accidents, low machine utilization and maintenance problems, low motivation among the local workforce, high turnover, excessive physical and environmental loads, and importation of inappropriate technology, can be dealt with via the application of ergonomics interventions. We claim here that healthier, safer, and decent workplaces will be the result of applying interdisciplinary and inclusive approaches that value ergonomics principles.

So the key question becomes how to make these professionals work together. A modest suggestion is to look at participatory approaches (see also participatory ergonomics and community ergonomics principles) to design and implement local initiatives for the improvement of the conditions of work. While researchers act jointly by combining their expertise, local initiatives can empower workers and employers in improving safety and health at work and ultimately ensuring continuous improvement (Kawakami and Kogi, 2005). The application of participatory ergonomics and community ergonomic principles

might prove beneficial within this context (for further information see Smith et al., 1994; Haims and Carayon, 1998; Haines et al., 2002). Furthermore, community-based participatory research (CBPR) is an important approach to redressing health disparities resulting from environmental causes and has been successfully implemented in some IACs. Today, this approach is being used to address safety and health issues at the workplace and to promote and sustain change among members of communities where vulnerable populations live and work (Arcury et al., 2001). CBPR is a joint process involving community members, community organization representatives, and researchers, in all aspects of the research process to enhance understanding of a given phenomenon and to integrate knowledge gained with action in order to improve the health and well-being of the community members (Israel et al., 1998). Engineers, public health, safety, and ergonomic professionals could adapt the CBPR framework for occupational ergonomics, safety and health intervention research within their local communities. In doing so, they will be contributing to the building of a strong community-wide support system and to the promotion of sustainable change.

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Part II

Participatory Approaches

4

Ergonomics Intervention in Industrially Developing Countries

Houshang Shahnavaz

CONTENTS

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4.1 Introduction

Ergonomics practice in most industrially developing countries (IDCs) is in its infancy. Almost two-thirds of the world's population has little or no access to the vast knowledge base that makes ergonomics such an important tool for the work environment and productivity improvement. While ergonomics has shown great potential in the "Industrialized World" by ensuring optimum technology utilization and proper technological development, interest and attention paid to the subject is very low among organizations and industrial managers in the IDCs (Shahnavaz, 1995).

The ergonomics literature of over half a century provides ample evidence of many successful interventions and their positive impact for both employees and employers in all sectors of society. It is commonly accepted that the application of micro- and macroergonomics is essential for improving working conditions, system efficiency and the promotion of the quality of working life. This experience, coming mostly from the industrialized world, has made ergonomics an acceptable discipline. However, despite such positive evidence, ergonomics is not yet widely known or used in a major part of the world, namely IDCs. It is therefore true to say that there is lack of awareness regarding the potential benefit of ergonomics in most IDC workplaces. Ergonomics as yet is not a global science.

A major effort is required to make it known as a useful and practical discipline in that part of the world which is most in need of ergonomics input, namely IDCs (Shahnavaz, 2002). Ergonomics intervention and its potential to deliver benefits have been accepted and practiced in only a small number of projects in IDCs, as not many decision makers are conversant with the breadth and depth of ergonomics (O'Neill, 2005). At present there are few practical examples to illustrate the benefits that can come from ergonomics intervention programs in these areas. However, with the appropriate type of ergonomics, there would be improvements in quality, productivity, working conditions, occupational health and safety, reduction of rejects, and increases in profit (Yeow and Sen, 2002).

4.2 Ergonomics Intervention

The term intervention refers to efforts made to effect change and render such change stable and permanent (Westlander et al., 1995). The objective of ergonomics intervention is to design jobs that are possible for people to do, are worth doing, protect and promote workers' health, and which give workers job satisfaction and a sense of identity with the company. An ergonomics intervention should therefore result in improving both the employees' well-being (health, safety, and satisfaction) as well as the company's well-being (optimal performance, productivity, and high work quality).

According to Hägg (2000) different types of intervention programs are identified with aims ranging from time-limited intervention to continuous processes. Common elements are health surveillance, workstation design and choice of tools, product design, quality aspects, participative aspects and education, training and relevant information. The implementation of ergonomics programs varies substantially depending on the type of company, company policies, and organization. Ergonomics intervention is a well-planned and structured process and must be a local activity that meets the particular needs of local people. In IDCs it should focus on utilizing available potential and resources of the local enterprise for planned improvement. Ergonomics intervention can take different forms such as

- Workstation improvement through physical changes (such as improving the workstation design and/or improving physical working environment and working conditions)
- Operator training (for qualitative changes of operators' perceptions and skills)
- Work organization change (for optimizing personnel and technological subsystems and for improving person–task and person–person interactions)
- Technology change (for improving person–machine or person–tool interaction)
- Work systems improvement (for optimizing system interfaces)

Factors affecting ergonomics intervention are management support and commitment, ergonomics awareness and know-how, employee participation in a democratic climate, motivation, organization and culture, legislation and inspection, and cost effectiveness of the intervention programs. According to Burgess and Turner (2000), "commitment is particularly important for the successful implementation of projects and strategic programs."

Worker participation is important for successful intervention. Participation of people involved in the program, in identifying problems and developing feasible solutions, is shown to be effective.

According to Kogi (1995), in view of the many constraints, special attention should be drawn to participatory ergonomics as an effective means of finding locally workable solutions. The success of low-cost improvements actually depends on the careful selection of feasible solutions, and local solutions have been shown to be effective and acceptable by both management and employees. It is suggested that one should select, with the help of appropriate support tools, low-cost improvements that can be built into work methods and equipment and are realizable by means of local skills and materials (Kogi, 1997a). Employee participation in the ergonomics intervention process is important because

- The employee knows his/her job better than any one else and possesses valuable information
- Being familiar with the operation, the employee can help to isolate the problem and find simple/specific solutions that are most cost effective
- The employee can and will accept responsibility for his/her work, health and safety
- Intelligence and creativity exists among workforces at all levels of the organization
- Worker involvement makes them more amenable to the enterprise
- The employee will accept and use the solution he/she has input to its development

Wilson and Haines (2001) pointed out that of all the advantages of participatory ergonomics, there are two direct benefits that are commonly referred to. First, employees have unique knowledge and experience of work. Therefore, their involvement should provide a clearer understanding of both the types of problems being encountered and the solutions that will be appropriate. Second, involving people in the analysis, development, and implementation of a change generates greater feelings of solution ownership and may generate a greater commitment to the change being implemented. In participatory ergonomics, the process of participation itself may provide benefits, with participants developing more self-confidence, competence, independence, personal development, social contact, feedback, influence, challenge and variability; the very characteristics that have been identified as contributing toward "good" work and reducing stress at work (Karasek and Theorell, 1990). Kogi (1997b) has also emphasized action-oriented interventions, where participation is especially important in a range of low-cost solutions. It is essential to develop an integrated change strategy emphasizing:

- Enabling methods that can lead people to immediate action in multiple aspects of work
- Participatory steps to active participation of local people
- Flexible use of support tools and techniques, and training about how and when to use these tools and group work techniques

4.3 Proposed Theoretical Model for Ergonomics Intervention Processes

Ergonomics intervention should be regarded as a process of improvement. As changes are continually going on in all aspects of an organization, it is better to establish an

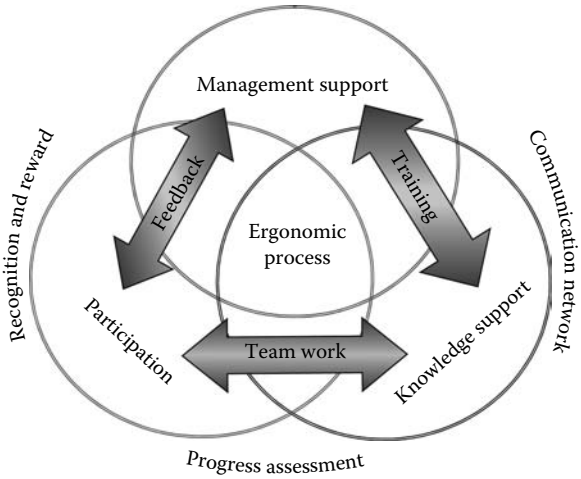

FIGURE 4.1
Proposed theoretical model for ergonomics intervention.

intervention process which is able to remedy all different kinds of problems which may occur as a result of changes in technology, organization, external and/or internal environment factors. A theoretical model to guide the ergonomics intervention process has been proposed and applied at several companies in Iran. The intervention process is based on three fundamentals, that is to say management support, knowledge support, and employee participation. The process starts with employee training, teamwork, and a feedback system designed and developed with the help of these three fundamentals. For the successful continuation of the intervention process, there is a need to design and develop a functional and acceptable progress assessment system, a recognition and reward system, as well as an appropriate communication network system for both bottom-up and top-down communication (Figure 4.1).

Training is an important part of a comprehensive, systematic approach enabling knowledge access within an organization, and implementation of the acquired knowledge in practice. An ergonomics intervention starts with training which will bring about awareness and action, aiding in the introduction of necessary changes. Training and transfer of ergonomics know-how is a dynamic process, where the external expertise, provided by the "knowledge support," i.e., the project supervisor or the ergonomist, acknowledges the individual experiences and talents of the trainees (the workshop participants) in a fruitful interplay. Ogden Brown (2005) describes the role of the ergonomist in the participatory ergonomics design and analysis process as that of a "change-agent, or a facilitator of change." This role can be varied and complex, and can be assumed by someone from inside or outside the organization. The intervention process is built upon trust, competence, relevance, and a strong tie to practical reality, which should be adjusted to the local needs and requirements, and to the cultural reality of the enterprises in which the intervention will take place.

Employees participate in the process as members of a "Working Team (WT)" involved in different project teams. They are trained in teamwork, participation, project design, systematic work, documentation, and follow-up activities. Further, they will be trained in basic ergonomics, identification of problems related to ergonomics, and productivity from a systems perspective, problem analyses, proposing feasible and applicable solutions to the

defined problems, and implementing cost-effective improvements. Selection of participants of diverse skills, as members of project teams, is recommended. This is because each is then able to work effectively with team members with different backgrounds, perspectives, and agendas, and each is potentially willing to limit personal autonomy in order to achieve the main objectives which link everyone on the team (Mankin et al., 1997). According to Imada (1986), participatory ergonomics involves contributions from several levels within an organization to identify, analyze, and solve ergonomically related problems.

Furthermore, management support and a democratic culture, which will be established as the result of teamwork training, are other important characteristics of successful ergonomics intervention. It must be noted that improvement is not a short-term activity, but a continuous process which requires long-term management commitment and support in terms of enabling this activity. By participating and giving approval to a feedback and reward system set up to encourage and motivate WTs, management makes them more committed to the company and its goals. A feedback system which is acceptable to all project stakeholders is necessary for success. This feedback provides, firstly, information to improve the training program and identify necessary corrective actions, and secondly, it reinforces a positive outcome and benefits of using learned skills in the workplace. It motivates members of the WTs toward continuous engagement and activity in their own teams. The feedback system should be designed with the employees' participation, considering the type and timing of the required feedback for various teams. Other important systems which must be developed to support a successful continuation of the intervention process include the "Recognition and Reward System," the "Progress Assessment System," and the "Communication Net-Work System."

The ergonomics intervention process should be evaluated at regular intervals by an assessment mechanism accepted by the stakeholders involved, to ensure its progress. The facilitator, together with representatives of work teams and of management should develop the "Progress Assessment System" and run a few trial exercises before defining the final system that should be approved by all project participants. Based on regular assessment of the ergonomics intervention process results, participants of the work teams who have achieved significant results and contributed to the progress of the company should be recognized and rewarded. The recognition and reward system should also be acceptable to all project participants. It is therefore advisable that this to be developed in participation within the company. Usually the achievements which contribute to increased productivity, work quality, reduction of wastes and rejected items, promotion of health, safety and satisfactions of employees, safeguarding the environment, and actions which increase the status and social acceptability of the company, will be recognized and rewarded. Further, the timing of recognition of the reward system is important and should ideally come not long after the assessment process. The results of the assessment and recognition and reward systems should be communicated to every participant and stakeholder in a transparent and effective way. It is therefore very important to establish a bottom-up and top-down communication system which ensures that every participant has all the necessary information required to be an active participant of the ergonomics intervention process.

4.4 Successful Ergonomics Intervention Case Study

A medium-sized company in Iran (which we shall call KH) with over 1000 employees producing detergent, washing powder, soaps, and other hygiene products, became interested

in an ergonomics intervention program in order to improve performance. After several meetings with the managing director and his advisors, the author was asked to propose a project for improving the situation in KH. A process was proposed in which the KH employees would learn to analyze their work and working conditions, and propose feasible improvement solutions. The author would act as a facilitator leading them through the process as a project supervisor. The project was designed in two phases.

4.4.1 Phase I: Macroergonomics Intervention

The first phase of the project involved a macroergonomics intervention process, proposed by the project manager (ergonomist) and approved by top management in the spring of 2006. The main objective of the first phase was to improve various systems and procedures of the company from a macroergonomics point of view. Systems and procedures such as sales, customer contact, productivity assessment, product quality assurance, employee motivation, human resource management, and employee promotion procedures, all of which top and middle managers were involved in and had faced some problems in solving, were addressed. The process started with a three day workshop outside the company premises in a pleasant environment, in which 35 of the company's top and middle mangers took part. The workshop was aimed to both formulate a vision for the company and develop a set of goals for reaching the defined vision. Management was made aware of the fact that the company needed to have a well-formulated vision and related goals, defined and accepted by all decision makers of the organization. In this way all managers of the organization would work to achieve the goals which they had contributed to formulating. As a result, the entire capacity of the organization would be directed toward a collective effort for accomplishing the defined vision. To this end, the company needed to formulate a set of clear and attainable goals leading the organization to its defined vision within a certain period of time. Thereafter, for each goal, the company had to develop a plan and program, identifying the activities required for reaching each individual goal (see Figure 4.2). According to Mullins (1996), a lack of employee commitment to an organization and its goals is a major constraint upon its performance and its ability to change.

The workshop started with a written questionnaire asking each participant to write down the vision of the organization and at least three goals for achieving the perceived vision.

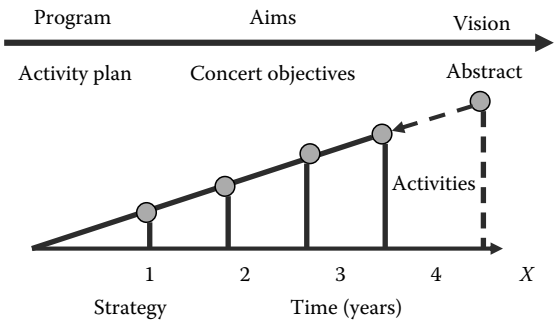

FIGURE 4.2
Development of an activity plan and strategies for achieving the goals (aims), and ultimately the vision within a defined time.

The questionnaires were collected and participants were divided randomly into five different groups. Each group received seven questionnaires to work within their group. The task of each group was to combine the submissions, finding similarities and differences between the various managers' perceived vision and goals. Thereafter, the groups came together and presented their findings. It was noticed that there were vastly diverse and sometimes contradictory ideas about the general vision and goals of the company. During the afternoon session, participants were informed about the key features of a successful and prosperous organization. Core values and related issues such as productivity, participation, and employee commitment, motivating factors, importance of adapting a holistic systems approach for productivity and quality of life were discussed. Employee values, customer values, environmental values, social image, and social values were also included in the exchange of views.

The next day participants were asked to work within their groups to develop new scenarios for the company's vision and related goals, based on the results of the questionnaires and the information gained from the discussion. They were also informed that the vision should have the following four elements: (1) it should be ideal and worthy of dedication, (2) it should be creative and inspiring, (3) it should be real and reachable, and lastly (4) it should be visual and possible to present pictorially. They were also asked to evaluate their scenario with the strengths, weaknesses, opportunities, and threats (SWOT) analysis diagram. At the end of the second morning, the groups got together and presented their scenario and SWOT analysis diagrams. The afternoon of the second day was devoted to combining the work of the five groups and defining the final version of the company vision and their related goals (see Figure 4.3). Three visions were formulated, as follows:

- Establishing KH as the leading and largest detergent and cosmetic products company in Iran
- Envisioning KH as being at the health and hygiene service of the society
- Seeing KH as moving toward becoming a world company

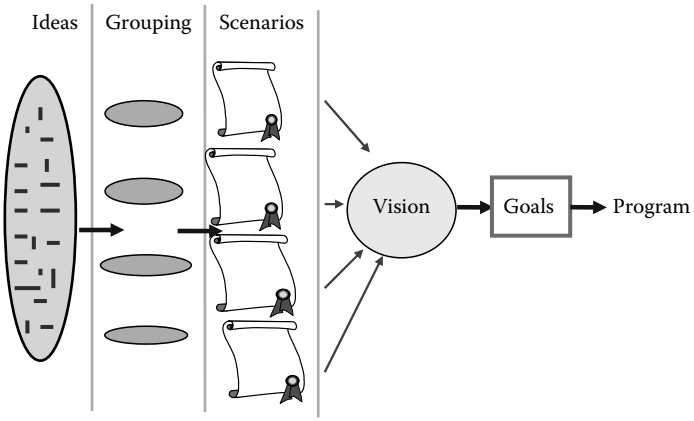

FIGURE 4.3
Developing vision and goals from participants' ideas and group work scenarios.

Thereafter, 17 different goals were identified and approved by participants for achieving these three visions as follows:

1. Increasing market share
2. Increasing number of products to complete the product basket
3. Innovation
4. Better marketing
5. Better human resource management (recruiting, keeping, and promotion of employees)
6. Customer centered company
7. Ensuring high productivity
8. More brands
9. Offering products at reasonable prices
10. Cooperation with large international companies
11. Better usage of opportunities for investment internally and externally
12. Improving product quality
13. Improving export
14. Homogeneous distribution of product within the country
15. Improving the chain of production from raw material to finished product
16. Improving company culture
17. Improving company image in the society

On day three participants came together to prioritize the goals. They then selected the first priority goal to work with. The workshop was interested to find out what problems existed from a systems perspective to achieve this goal, and to find practical solutions for them. This task is best achieved using the "Future Workshop" (FW) technique (Jungk and Müller, 1987; Skoglind-Öhman and Shahnavaz, 2004). The FW technique was described to the participants and the problem experienced by participants of achieving the goal of *high productivity* was selected as the workshop theme. User's guides for workshop leaders and workshop participants prepared by Mohammed-Aminu Sanda (2006) were given as a reference.

FW is a well-structured process with the following five phases:

1. *Preparation phase*: The "theme." "Problems related to improving productivity" was selected as the theme for this workshop.
2. *Experience phase*: Also called "critic phase." A complete "problem catalogue" was developed in this phase.

Each participant wrote down just one problem at the time, something which she/he had experienced as significant with regard to the workshop's theme. The problems were then written on poster-size paper which everyone could see. Then, the next round started, and this went on until no further problems could be identified. Thereafter, each participant prioritized three problems central to the theme. Each participant had seven credits to vote, which were divided between three problems. The first and second problems received three credits each and the third just one. The workshop facilitator selected six titles that covered

all the problems which received credits. By considering a holistic system approach, problems were categorized under "technology," "management and organization," "internal environment," "external environment," "training and skill," and "information." Problems which received credits were then placed under a relevant title. Participants were asked to select one of the six titles which they had an interest in, and the knowledge to unfold and propose possible solutions. Then the six WTs began working on phase three.

3. *Fantasy phase*: Developing future solutions. Participants had many ideas that had never been expressed because they deemed the situation to be ideal. In the fantasy phase there are no barriers, no economic, personal, technical, or organizational limitations. WT members expressed their fantasy solution for the selected problems. Solutions were written down on large sheets of paper. The groups got together again and presented their work with the others and discussed its relevance.
4. *Strategy phase*: The aim was to go through all the written fantasies and to identify the barriers regarding their realization. In this phase participants learnt different techniques, such as "Desirability and Possibility Assessment Model" (desirability and possibility of a solution application are assessed in a square diagram of 0–100 scale), "Circle Model or Development Model Activity (Engeström, 2000)," "Triangular Model (Engeström, 1987)," and "Cause and Effect diagram (Fish-Bone Diagram)." Due to the shortage of time each WT was required to develop applicable solutions for one of the problems. It was decided that the groups should meet once a week for three hours over the next four months to discuss other problems.

After four months, the WTs gathered in a general meeting and presented their work in a two day workshop. During the first day, the WTs presented the results of their past months' activities, followed by a group discussion. Then the results of the WTs were collected. On the second day, another "future workshop" was conducted, selecting the problems related to the second goal. The process was planned to continue until all the problems related to achieving the defined goals were solved. At the end of the third day, the project facilitator presented a model for the future activities (Figure 4.4). The participants were divided into four WTs and two "Expert Groups" (EGs). The results of the WTs activities were passed on to the two EGs. Members of the EG were selected from the most knowledgeable employees and those with recognized experience in the subject. Their task was to review the work of the WTs and propose final and applicable solutions for improving the identified problems. The project of "ergonomics intervention process" was estimated to take three years to complete. After each workshop a complete report is prepared, containing a summary of the workshop, the critical catalogue developed at the FW, the final report of each WT, the findings and final improvement solutions proposed by the EGs as well as the future activity plan. The report is then distributed to all stakeholders.

5. *Action phase*: This involves input of the EGs. The EGs, after improving the proposals of the WTs, send their final proposals to the MD for approval. After his approval, proposals are implemented either by the employees themselves or by external resources. A group of specialists designated by the MD will continuously assess the application results and give feedback to the MD. Further, the application results must be fed back to the WTs as well as the EGs for eventual improvement.

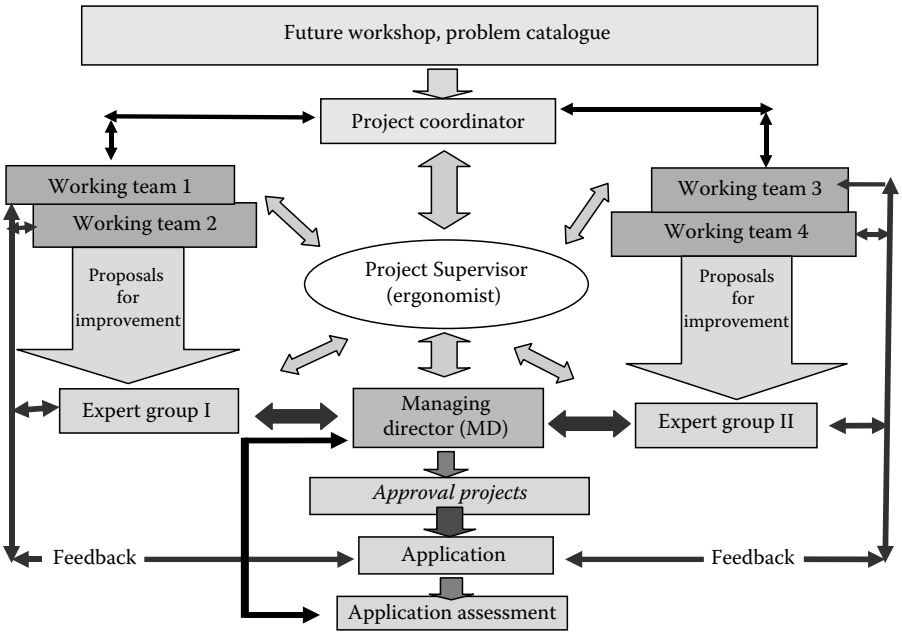

FIGURE 4.4
Proposed model of work within the ergonomics intervention project.

A female employee was appointed as the project coordinator for the whole project and was in direct contact with the project supervisor. The project coordinator's task was to make sure that WTs and EGs meet regularly according to the planned schedule, document their activities, and send a standard report form after each meeting to the project coordinator. Further, the coordinator should be a support person for the WTs and a contact person between MD, project supervisor, WTs, and EGs. She is also responsible for proposing appropriate rewards for the WTs and EGs with high performance at each general meeting, usually every 4 months.

After a year into the project, many solutions for improvement were proposed by the WTs, and a good number of them were improved by the EGs. Several of the proposals were then approved by the MD and later by the board of company directors, and were finally put into action. Among them were a new procedure for recruitment and promotion, an improved system of customer service, a new system of productivity assessment and improvement of different departments and units based on ProMES proposed by Prichard (1995), and an improved system for marketing and quality assurance.

4.4.2 Phase II: Microergonomics Intervention

KH comprises several factories and the oldest and largest is located near Teheran. This factory produces many different detergents and cosmetic products and has over 700 employees. The company MD agreed to the proposal to conduct a microergonomics intervention process at this factory for improving the working conditions and productivity as the second phase of the overall intervention process.

This process started with a two day workshop conducted, like the first, outside the factory in a pleasant environment. Thirty five male production and line managers of the

factory, together with the factory director and deputy directors, participated in the workshop. The aim of the workshop was to create ergonomics awareness among participants and to teach them ergonomics methods and tools for improving working conditions, environmental conditions, as well as productivity. The workshop started with introducing the *Ergonomic Checkpoints* booklet (ILO, 1996). The project supervisor explained its content and showed participants how to use it at their workplace. This book has been translated into many languages, among them Farsi, and is one of the most used materials in IDCs by the author and many other scientists and professionals. While it has been used in IACs, it has been primarily used in IDCs (Scott and Shahnavaz, 1997).

In the afternoon of the first day, participants were divided into seven teams to work with the ergonomics checkpoint material. This material includes 128 checkpoints related to nine different areas of ergonomics, i.e., material storage and handling, hand tools, productive machine safety, improving workstation design, lighting, premises, control of hazardous substances and agents, welfare facilities, and work organization. Each team was assigned to work with all 128 checkpoints, trying to understand the "why" and "how" of each checkpoint and were tasked to discuss the material from their own work experiences, especially the experiences from their current workplace. They were also asked to write down their collective experiences in respect of each checkpoint, indicating if they proposed action at their current workplaces, and if so, its priority. As the time of the workshop was very limited they were advised to select just a few checkpoints for this workshop and to continue their work after the workshop at the regular meetings planned for the future according to the planned activity diagram (Figure 4.5). Thereafter, teams came together and each presented its work to the other teams, discussing their decisions regarding their proposed action and its priority, and presented their solutions for the identified problems. Despite it being the first time, they worked together as a team identifying a shop floor

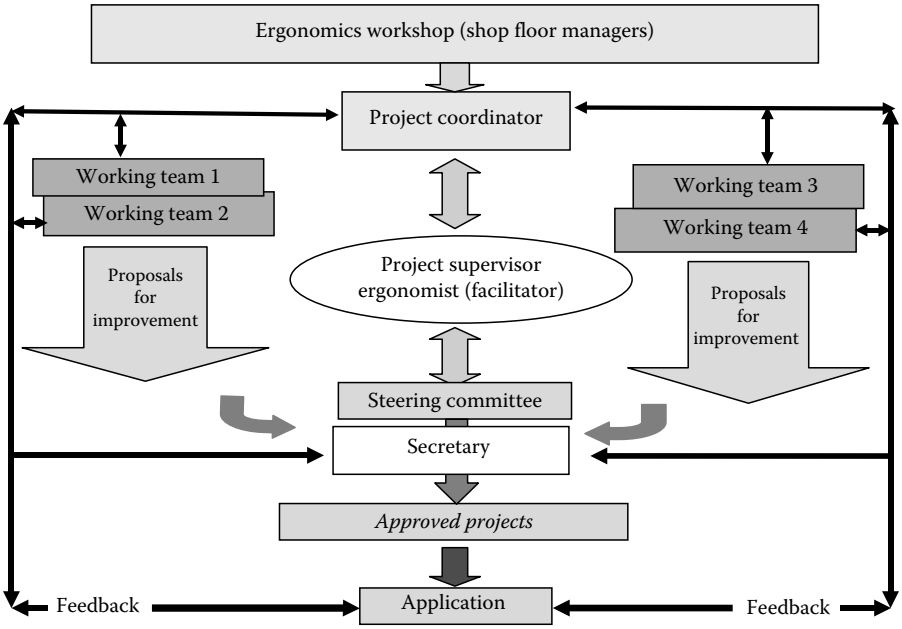

FIGURE 4.5
Activity diagram for factory line and production shop floor managers.

problem and proposing solutions, they came up with very good local no-cost/low-cost solutions during this short time. This greatly motivated the participants and they were all very excited to continue their work. After the workshop, the project supervisor, together with the project coordinator and the factory director, selected members for the steering committee (SC). Apart from the factory director, three of his deputies were selected for this committee. The list of activities below was presented to and approved by the SC.

Major activities of the SC:

1. Developing policy and procedures for WT activity, providing times and scheduling an appropriate place for their group meetings and activity at the factory.
2. Assessing and documenting WT activity and giving regular feedback to the WT.
3. Supporting WT and rewarding good work.
4. Evaluating WT proposals for improvement and if approved, allocating resources for its application. This activity should be conducted in a meeting with WT leader and WT coordinator present, and should not be later than 15 days after receiving the proposal.
5. Designing an acceptable reward and feedback system.
6. Evaluating the applied projects at regular intervals and the changes that had been made as the result of WT activities, and enabling continuous improvement.
7. Sending regular activity reports to the project coordinator.

As indicated in Figure 4.5, proposals for improvements in the form of separate projects designed and developed by the WTs are sent to the SC secretariat. A female employee of the factory was appointed to do the administrative work and act as secretary and as contact person between the SC, the WTs, and the project coordinator. Her tasks included documenting all activities and making sure that WTs and the SC held regular meetings and facilitate effective flow of information.

Major activities of the WT:

1. Studying and discussing all the 128 ergonomics checkpoints within their WT.
2. Selecting workstations for improvement and identifying problems in cooperation with the operators in charge.
3. Checking every workplace in their assigned area, with full participation of the operators in charge, and identifying work-site problems and proposing feasible and applicable ergonomic solutions to the SC.
4. Evaluating WTs progress at regular intervals and sending feedback reports to the SC.
5. Documenting WTs activity and sending regular standard written reports to the SC and the project coordinator after each group meeting.
6. Cooperating in the implementation of proposed improvements following approval by the SC.
7. Distributing ergonomics information to other employees in their work area and creating an awareness of ergonomics on the shop floor.
8. Developing new checkpoints (explaining reasons and methods) specific to their workplaces and trying to improve working conditions continuously.

4.4.2.1 Assessment of the Implemented Proposals and Evaluation of Their Effectiveness

The rewards system was designed to recognize the WTs' achievements and motivate employees for future commitment and further engagement within WTs. Four criteria were suggested and agreed to by the SC for assessing the effectiveness of the proposed project and deciding on the type of reward to be given to the WT:

1. Increased productivity
2. Economic savings (due to savings in energy and resources, and reduction in waste and reject products)
3. Increased safety and health
4. Increased worker satisfaction

In cases where the implementations are carried out by the WT who proposed the project, then the following factors were considered in selecting the award type for the WT:

- Correct assessment of project cost and the needed resources within reasonable limits
- Correct assessment of project implementation time and duration within reasonable limits
- Smooth and proper conduct of the implementation by the WT

Implemented projects need to be evaluated by the SC on a regular basis. The first evaluation occurs immediately after project implementation, the second usually 3 months later and the last, after 1 year. Project evaluations are conducted in the presence of the WT coordinator. The total credit that each implemented project can receive is 100 points, which are divided into the following four factors:

1. Increased productivity (maximum of 35 credits) based on the collected information and data by the SC
2. Economic saving (maximum of 35 credits) based on information and facts collected by the SC
3. Increased safety and health (maximum of 20 credits) based on recorded information
4. Increased worker satisfaction (maximum of 10 credits) based on operators' subjective assessment, as collected by the SC

4.4.2.2 Reward Categories According to the Achieved Credits

Rewards are given to the WT, and all its members receive an equal share:

1. *Credits 1 to 20*—Written certificate, record in the employees' file and announcement in the monthly journal of the company
2. *Credits 21 to 30*—As for 1, plus an announcement of the employee's name and his/her achievement at the annual and other big ceremonies
3. *Credits 31 to 100*—As for 2, plus a financial reward

The maximum financial reward is approximately 25% of the total one year productivity gained due to the implemented proposed project and/or 25% of economic saving. It was decided that a quarter of the year's gain should be given to the idea and three quarters to material, overhead and labor cost of implementing the changes. The proposed financial reward categories and limits are a general guideline and are regarded as flexible. In cases of significant gain in productivity and or cost saving due to the implementation of an exceptional proposal, the SC together with MD can suggest higher financial rewards to the members of the WT.

4.4.3 Discussion and Successful Examples

The above process, after just one year, has resulted in many benefits both for the factory management and employees. The benefits can be categorized under direct benefits or indirect benefits as follows:

Direct benefits: Performance of all units has been improved because of WTs' activities and implementation of the ergonomics checkpoints within factory workplaces. The WTs proposed several no-cost and/or low-cost solutions to small and medium problems at their workplaces, which were implemented using local resources. These changes included improvements such as providing tables for work done previously on the floor, e.g., welding and safeguarding moveable machine parts; sorting and providing extra places for different waste materials; better lighting for workplaces and corridors; energy saving measures; coloring workplaces with attractive colors; better housekeeping; and minimizing material handling by building conveyer belts. In short, all 128 checkpoints emphasized in the ILO checkpoint book were checked, and where necessary improved. It was observed that many checkpoints needed to be considered at the different workplaces. According to Kogi (1997a), the success of low-cost improvements actually depends on the careful selection of feasible solutions. It is suggested that one should select, with the help of appropriate support tools, low-cost improvements that can be built into work methods and equipment, and which are realizable by means of local skills and materials. This was exactly what was done in this case. Further, as a result of the WTs' activities during the year since the project started, three WTs have already received financial rewards for their proposed and implemented cost saving projects.

The first case meriting financial reward involved the design and development of an alarm and stop signal for a conveyer belt. The operator's task, working at the end of the belt is the packing of tubes and detergent bottles into large cardboard boxes. In the past, employees had to sit and watch the process and check the availability of glue and tape, and were required to fill the glue container or change the tape when needed. This process resulted in a waste of materials as often glue containers became empty, and boxes came out of the system without being properly packed, causing waste and double work. Now, with the design and installation of the alarm and stop signal, the boxes are stopped as soon as the glue container is empty (or the system runs out of tape) and the operators are alerted to refill the glue container or install new tape. This new design has saved material and labor cost. The project was proposed by a WT, designed and developed within the factory by the factory engineers, costing very little compared to its cost saving benefit for the factory. The SC evaluated this project after it had been in operation for three months, and regarded it as the best proposed project. They awarded the WT responsible for it a cash reward together with a certificate for the team members and announcement in the monthly company journal. The second case involved the design and development of an alarm and stop system for informing operators about a problem of the product registration machine.

In the past many products came out of the system without being registered due to different technical problems such as print ink running dry. Now with this new alarm and stop system as soon as a product is not registered the system will be stopped and operators are alerted. This improvement has saved material and double work, and increased the system performance. The SC, after evaluating the outcome of this project, presented the WT with a cash reward because of the significant saving in material and human labor. The third case involved the designing and building of an extra storage place in the existing storage room by utilizing the available space more efficiently. The SC presented a cash reward for this project, which both improved storage space significantly and minimized product damage. All these projects were implemented using factory resources. Several other projects were also proposed by the WTs and are under construction or assessment by the SC. This work is scheduled to continue at least for three years.

Indirect benefits: The process initiated an active and conscious development environment at the factory. Employees are now vigilant about their working conditions and are committed to cooperate and find solutions to problems identified. There is an atmosphere of competition between the WTs, each trying to come up with better cost saving or productivity improving proposals. According to the factory management, the motivation among employees is now much higher compared to previous years. They are more committed to their work and use their creativity to come with new ideas. There is better communication and KH is benefiting from utilizing its resources, especially its human resources, much more effectively than before. Employees are more engaged in company affairs and help in solving problems and contributing to KH progress.

4.5 Conclusion

This ergonomics intervention process started with phase one, a macroergonomics intervention and, after a year, the second phase which concentrated on microergonomics intervention was introduced. The microergonomics interventions resulted in some tangible improvements sooner than the macroergonomics changes. It can be concluded that changing administrative procedures and people's attitude and ways of working was not easy among administrative personnel. They needed more time to achieve results compared to engineering and physical changes. According to Hendrick (1995), an important outcome of macroergonomic intervention is a culture change, where the organizational culture is primarily defined by the organization's core values, but which also includes traditions and unwritten rules. This cultural change, however, is a slow continuous improvement process, not a short-term activity. It requires long-term management commitment to continuously adapting and improving the program. The ultimate goal of ergonomics intervention is, however, to optimize work systems at both the macro- and microergonomic levels.

During the 1990s, the interest in ergonomics issues in a wide sense had grown within enterprises of the industrialized world. This was the result of an increasing awareness of the importance of those matters for corporate core values such as productivity, quality, and an inevitable change process (Wilson, 1999). Experiences from industrialized countries show that consideration of macroergonomics is a significant contributing factor for creating the appropriate working environment in which people are motivated to participate and better utilize company resources for increasing system productivity. According to Hendrick (2002a) when the goals of macroergonomics are achieved, the result should be

dramatic improvements in various aspects of organizational performance and effectiveness. Productivity improvement is a key issue in IDCs, where the level of productivity in general is much lower compared to similar production systems in the industrialized world. A combination of micro- and macroergonomics interventions will achieve improvement in the total system performance. Scott and Charteris (2001) also emphasized that it is necessary to include both microergonomic and macroergonomic approaches. Instead of evaluating the relative merits of the two approaches, one needs to acknowledge their complementary interdependence, where the ratio between their inputs will vary according to the situation being addressed.

Using a systematic process of macro- and microergonomics interventions, the author conducted an intervention project at a process industry in Iran between 1995 and 1997. Developing a new organizational system, which made full use of employee's participation and potentials for problem solving, increased the company profit by over 100% after a year. This has resulted in a significant increase in all employee wages through profit sharing. The increase in both productivity and profit was due to better utilization of both human and material resources which was achieved through training, increasing employees' competence and commitment, participation and organizational readjustment (Helali and Shahnavaz, 1996). In the case of KH, we started first with macroergonomics, trying to make top management of the company aware of the potential benefit of ergonomics. They were informed about different methods using participatory procedures for motivating and involving employees in reconsidering their work procedures and methods. During the course of the project it was apparent that the administrative personnel needed much encouragement and motivation to adjust their daily routine and propose some changes. The process started with some hesitation among some members of the WT, but it soon gained momentum and after four months many suggestions and proposals for improving the working procedures were presented at the general meeting. These proposals were then given to the EGs to finalize and prepare workable versions of the new methods and procedures for approval by the managing director and later by the board of directors. After 6 months, three new procedures for better human resource management were approved and put into practice.

There are different suggestions regarding different forms of ergonomics intervention and the results of interventions. For example Hendrick (1994, 2002b) indicates that instead of the 10%–25% improvements in the system effectiveness that many ergonomists have experienced from successful microergonomics interventions, one can achieve improvements of 60%–90%, or more from macroergonomics interventions, as documented in several cases (Hendrick and Kleiner, 2001). Hendrick (2002a) suggests that the ergonomist or ergonomics team has to begin by making microergonomic improvements that yield positive results within a relatively short period of time (often called "picking the low hanging fruit" strategy). When managers see these positive results, they become interested in supporting further ergonomics interventions, and over time senior management comes to support progressively larger ergonomics projects that actually change the nature of the work system as a whole.

However, it should be noted that implementing changes in workplaces requires that both macro- and microergonomics views are considered and linked together (Kleiner, 2004). Whether one starts at a macroergonomics level or with microergonomics interventions depends mostly on the type of intervention, the magnitude of the problem, as well as management decision. Whether the intervention is conducted by an outsider or in-house expert (ergonomist), starting with microergonomics will probably produce quicker positive results which are likely to motivate management to support

further ergonomics intervention. However, an intervention which aims to start a process of change by mobilizing employees' participation and commitment could be most successful by starting with a macroergonomics intervention. Through a learning process supported by management, a change process will start in which motivated employees working in various teams will identify various productivity, health, and safety problems and propose workable solutions. The author, after working for more than 30 years in various IDCs, is convinced that ergonomics intervention in IDCs will be best-achieved through macroergonomic input, which will trickle down even to no-cost/low-cost microergonomics improvements. If traditional management thinking and the hierarchical structure of management in which most employees passively wait for management orders is altered by better utilization of human resources and by encouraging workers participation, then many new ideas and improvements are possible.

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5

*Participatory Ergonomics Training for Networking Farmers**

Tsuyoshi Kawakami and Ton That Khai

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5.1 Introduction

Participatory ergonomics training is widely applied in Vietnam and other countries in Asia for improving safety, health, and working conditions of various workplaces (Kogi, 1995). The Work Improvement in Neighborhood Development (WIND) Training Program provides a typical example of the participatory ergonomics training specifically designed for farmers (Kawakami et al., 2005). The training uses action-oriented, easy-to-apply tools such as action-checklists and photo-sheets showing local good examples, and provides direct support to farmers in order to strengthen their self-help improvement initiatives. Participating farmers start with simple, low-cost improvements (Kogi et al., 1988) that can be carried out by using locally available materials, and are then challenged to progress to more innovative improvements in a stepwise manner. Basic ergonomic improvements, including better materials handling methods, less strenuous work postures, easy-to-use hand tools, and the insertion of regular breaks, are typical examples of such low-cost improvements.

Practical, participatory ergonomics training has encouraged many farmers to support these improvement actions. Vietnam, for example, has widely applied the WIND

* The opinions and assertions contained within this chapter should not be construed as representing those of the International Labor Office.

training program and trained active farmers in basic ergonomics and occupational safety and health (OSH). The trained farmer trainers, called "WIND farmer volunteers," have assisted their neighboring farmers in improving working conditions and have sustained and expanded the network of participatory ergonomics training. Locally adjusted ergonomic training tools support the action of these farmer trainers. This chapter explains the experience of participatory ergonomics training using the WIND training program in Vietnam.

5.2 Steps in Participatory Ergonomics Training for Farmers

Participatory ergonomics training consists of initial training workshops and follow-up activities for networking and sustainability. Figure 5.1 shows the steps of a WIND training workshop for WIND farmer volunteers, and its follow-up procedures. The WIND training relies on farmers' self-help initiatives and its program is designed to assist participating farmers in identifying practical solutions which can be implemented at low-cost by using locally available materials.

5.2.1 Applying Action-Checklists

Participating farmers visit a farm and the farmer's house at the beginning of the WIND training program and explain the application of action-checklists. Table 5.1 shows 42 checkpoints adopted in the WIND training program. The action-checklist helps participating farmers to consider multiple aspects of their work and improvement needs (Figure 5.2). The action-checklist is associated with illustrations showing practical improvement ideas for easy-understanding. It is not a comprehensive list covering all ergonomics action points, rather the action-checklist focuses on common, available solutions and helps participating farmers start thinking of practical improvement ideas. The WIND checklist can be downloaded from the Work Improvement Network Asia (WIN-Asia) Web at www.win-asia.org.

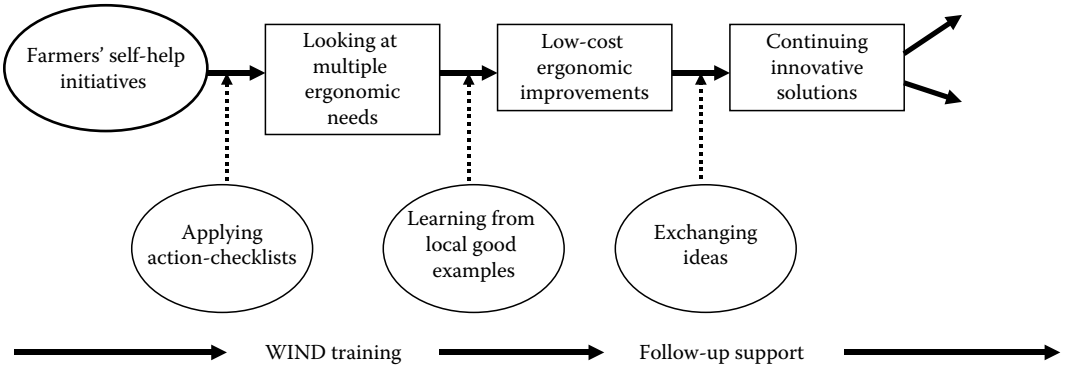

FIGURE 5.1
Steps of participatory ergonomics training and follow-up support.

TABLE 5.1

Ergonomic Checkpoints Listed in WIND Training Manual

Materials storage and handling: 1, clear passageways; 2, eliminating height differences; 3, bridges; 4, multilevel shelves; 5, containers; 6, hand trucks; 7, larger wheels; 8, conveyors
Work stations: 9, work height; 10, chairs; 11, changing postures; 12, easy reach; 13, easy-to-use tools; 14, home for tools; 15, fixtures
Machine safety: 16, purchasing safe machines; 17, guards; 18, feeding devices; 19, emergency controls; 20, safe use of electricity
Work environment: 21, ventilation; 22, daylight; 23, heat and cold; 24, selecting safer pesticides; 25, safe storage of pesticides; 26, pesticide labeling; 27, handling used pesticide bottles; 28, information sharing; 29, animals
Welfare facilities: 30, drinking water; 31, regular meals; 32, hygienic latrine; 33, resting corners; 34, protective devices; 35, first aid; 36, maternity protection; 37, protecting children
Work organization: 38, work layout; 39, short breaks; 40, regular holidays; 41, community cooperation; 42, family responsibilities

FIGURE 5.2
Action-checklist exercise by women farmers.

5.2.2 Learning from Local Good Examples

After the initial farm and house visit with the action-checklist application, WIND farmer volunteers show local good examples to participating farmers by using photo-sheets (Figure 5.3). The local good examples cover six essential ergonomic areas: materials handling, work posture, machine safety, work environments, work-related welfare facilities, and work organization. These local examples illustrate what farmers can do by using available materials and facilitate their improvement actions.

FIGURE 5.3
A woman farmer trainer trains neighboring woman farmers by using a photo-sheet booklet that shows local good examples.

5.2.3 Group Discussions

Participating farmers discuss ergonomic improvements based on the action-checklist results and propose improvements to the farm and house which they visited. They are advised to first look at simple, low-cost solutions that can be done by using available resources. The trainers serve as facilitators in the discussion with the farmers and do not tell them what to do. The participants present their improvement ideas. Before the end of the training, the participants develop their action plans for their own farms and houses.

5.2.4 Follow-Up Visits for Networking the Former Participants

WIND farmer volunteers together with local ergonomists and OSH practitioners make follow-up visits to the farmer participants 2–3 months after the initial WIND training workshop. Farmers usually implement their initial, low-cost improvements before the first follow-up visit by the trainers. The follow-up visits are important for learning about the improvement efforts of the farmers and for encouraging them to continue innovative improvement actions.

All farmers who have participated in the WIND training have implemented many improvements using low-cost improvement methods (Figures 5.4 and 5.5). Trained farmers start improvements in simple, practical ergonomics areas such as materials handling, work posture, or work layout changes. Typical improvement examples include homemade hand trucks for carrying heavy materials, improvements to paths and bridges to ensure safe transportation, improved workstations for better posture, and the insertion of more frequent short breaks.

WIND trainers also organize achievement workshops instead of follow-up visits. Previously trained farmers are invited to gather together and exchange their improvement

FIGURE 5.4
Wheeled heavy machine for safer carrying.

FIGURE 5.5
Tool with a longer arm to collect dried rice easily.

experiences and ideas for future actions. The achievement workshops are opportunities for networking participating farmers to form long-term goals, and the trainers collect newly developed improvement examples. These new improvement examples are then included in the next WIND training session as powerful local good examples.

5.3 Roles of Participatory Trainers and Training Tools

WIND farmer trainers play facilitator roles and assist farmers in identifying their improvement points and low-cost solutions. The trainers do not tell farmers what to do. Instead, they use practical ergonomics tools effectively to support the self-help efforts of the farmers. Once the farmers have made the initial low-cost improvements, it increases their confidence to make more positive changes in their working and living conditions, and they can then be challenged to try more innovative, costly improvements. They pay increasing attention to the wider aspects of the working conditions including machine safety, safe use of electricity, or safer methods of spraying pesticides. Farmers who have experienced practical ergonomics improvements often look at agricultural production methods and start new agricultural products for better income generation.

Participatory ergonomics training tools have assisted farmers in accelerating their improvement efforts. The action-checklists have helped farmers look at multiple improvement needs systematically and to find feasible solutions. Illustrations and photo-sheets showing local good examples assist farmers in knowing some of the available improvement options within their communities. Group discussion methods facilitate the exchange of ideas among the farmers and enable them in developing practical solutions. The practical, easy-to-apply training tools have been widely applied by farmers and have supported their improvement actions.

5.4 Networking Farmers for Wider Coverage

Local ergonomists and safety and health practitioners in Vietnam have been networking trained farmers and farmer trainers in order to achieve sustainability. They have also identified and mobilized existing people's networks for widening participatory ergonomics training. The Department of Health of Can Tho city, for example, used the network of rural health centers and retrained the staff as participatory ergonomics trainers by using the WIND training program (Khai et al., 2005). These trained health-center staff have conducted the WIND training in their respective villages. Between 2001 and 2007, 1,545 farmers were trained as WIND farmer volunteers. These farmer volunteers in turn trained 27,061 farmers and their families. As a result, the health center staff collected 246,642 improvement examples in working and living conditions implemented by the trained farmers.

Learning from the successful experiences in Cantho, Vietnam has further strengthened multiagency networks to support farmers (Kawakami et al., 2008). Provincial departments of labor, health, and agriculture and farmers' unions and women's unions established joint technical teams. The five agencies have their own channels to reach farmers and support staff at village or district levels. From 2004 to 2007, 14 Vietnamese provinces have launched these multiagency networks and trained 7,922 farmers. They implemented 28,508 improvements comprising 6,679 improvements in materials handling, 5,220 in work posture, 2,981 in safe use of electricity and machinery, 6,210 in working environment and hazardous chemicals, and 7,418 in welfare facilities. This successful networking was possible because of the existing channels of local people. Practical, easy-to-apply ergonomics training methods activated their human networks.

5.5 Conclusions

Participatory ergonomics training strengthened the self-help initiative of farmers to improve their working conditions and work methods. Good practice approaches, focusing on local improvement efforts and achievements, were a key to the success. Many farmers actively participated in low-cost improvement actions starting with simple, feasible measures including better materials handling methods or workstation designs. Practical, locally adjusted ergonomics tools such as action-checklists and photo-sheets showing local good examples accelerated the improvement actions by the local farmers. Visible improvements increased the confidence of farmers to make positive changes and motivated them toward further improvement actions. Existing networks of local people as well as the government networks have played vital roles in expanding the coverage. Participatory ergonomics training and building on local initiatives will continue to assist farmers and workers at grassroots level in improving their working conditions and work efficiency.

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6

The Practice of Ergonomics in the South of Brazil from a Sociotechnical Perspective

Lia Buarque de Macedo Guimarães

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6.1 Introduction

Ergonomics in Brazil was initiated in the 1970s and at that time was influenced by Alain Wisner, which justifies the fact that most ergonomics studies in Brazil follow the French approach of AET (in French *Analyse Ergonomic du Travail*). In the 1990s, another method proposed by Professors Anamaria de Moraes and Claudia Mont'Alvão gained strength mainly due to its clear framework for understanding and labeling of the many constraints which crop up in an ergonomics study. Despite the differences in the terms used, both AET (Guérin et al., 1991) and the systematic approach proposed by Moraes and Mont'Alvão (1998) are descriptive, in that they require a very detailed diagnosis, but they do not

necessarily lead to the application and further evaluation of work improvement. Also, both approaches are top-down, relying on the expertise of the ergonomics specialist, and not necessarily depending on the workers and managers to carry on the intervention.

In the last 15 years, I have been working on the development and application of a more bottom-up approach in order to start an ergonomics program that could make a difference in the lives of employees in addition to enhancing productivity. It was very clear to me that ergonomics in Brazil would have a hard time if it had to keep relying only on the social aspect, or the personnel subsystem, but it would have a chance of survival if it added what entrepreneurs like most—the profitable aspect supposedly driven by the improvements in the technological subsystem. For people running a company, human beings in general mean a necessary cost, while good technical solutions mean benefits. The sociotechnical approach to ergonomics, or macroergonomics, aided by measuring results with quantitative data supported by statistical analysis (that can be followed by qualitative data) proved to be the way to make a difference in the Brazilian industrial system. One of the most important aspects of the method, which I called Macroergonomic Work Analysis (MA), is a feature of action research. The idea is not to carry out a descriptive research but in fact to propose, implement, and evaluate a change together with the employees, relying not only on the expertise of the specialist in ergonomics but also on the workers' tacit knowledge.

An ergonomics intervention with a sociotechnical approach is particularly important in Brazil, since the industrial system is based on low levels of technology, which impact negatively on both productivity and safety, and on human resources who are not well prepared for their jobs. The reason for such a situation lies in the type of colonization Brazil experienced from when it was discovered in 1500: the country was built, first, to deliver natural resources (such as wood and gold), and later, to grow food (like sugar and coffee and, nowadays, soya beans) for the colonizers. Industrialization was never an issue for the country's development because this would have prepared the country to compete with the more advanced ones. Besides the undesirable competition, the development of Third World countries would offer the most powerful countries, they would also lose the market for their products. In the colonial period, any kind of industrialization was forbidden by law (Heynemann and Vale, 2003), which forced Brazilians to use the end products brought from abroad, and, what is worse, built up the idea that only foreign products were of good quality. This situation did not change even after independence in 1822. In his study on the economic Brazilian formation, Furtado (1959) made it clear that the many limitations imposed on the installation of a strong industrial system in the country had a deep negative influence on the establishment of its economic structure, defining an indirect development dependent on the industrialized countries. As stated by Jaguaribe (2006), even nowadays the Brazilian dependence on external capital and technology is so intense as to leave no room for native technology to develop.

In the international division of labor, favored by liberal and uneven free trade agreements, Brazil, along with other Third World countries, still has a goal of supplying the developed world with the resources they need, and of buying what the advanced countries choose to export back to it. In the 1960s and after, the drive for industrialization in Brazil was based on multinational companies that were looking for places to produce a very large number of products with a lower level of quality (characteristic of a Taylorist/Fordist mass production). This low-cost production is achieved in plants where the production costs are lower than in the main plants in the original countries, i.e., where technology does not have to meet safety standards and human resources accept trading unsafe and unskilled work for low wages. Because this type of economy does not rely on cutting-edge technology or a highly qualified workforce (29%) of the Brazilian population, according to the latest census, earns BR$80

a month or US$44 (Fundação Getúlio Vargas, 2001) in jobs requiring a very low level of school education. It is important to note that at the time of the 2000 census, a minimum wage was BR$151 or US$84. The same Brazilian census (IBGE, 2002) showed that 63.2% of the Brazilian population had less than eight years of schooling (an incomplete first grade level of education), only 16.3% have second grade, and 6.4% a university level.

Besides that, according to IBGE (2008) based on the 2006 National Research for sample of domiciles (Pesquisa Nacional de Amostra de Domicílios [PNAD]), nowadays, Brazil has a large income inequality (24.9% of Brazilians live on less than one minimum salary per month, BR$350 or less than US$167), while 0.5% earn more than 20 minimum salaries per month (or US$3350). According to Barros et al. (2007) based on the Gini coefficient, only 10 countries in the world (seven in Africa and three in South America) are worse than Brazil in terms of income concentration. The difference between the income of the richest 10% of the population and the poorest 40% is up to 32 times. The richest 1% of the population has the same amount of money as the poorest 50%. The richest 10% hold more than 40% of the income, while the poorest 40% have less than 10% of the total income. While 64% of countries have a lower per capita income than Brazil, only 43% have their poorest 20% with a per capita income that is less than in Brazil. When we add to this a high level of unemployment (10% on average), deficiencies in social protection and labor laws, we get an economic and social situation that facilitates the adoption of deficient work organization and explains the overall bad conditions of most workplaces in Brazil today. On the other hand, it can be said that this situation elevates ergonomics as an important discipline which can help build a better country, a change that must arise from the base of the social pyramid to the top (i.e., a bottom-up approach), and which needs to engage workers, managers and, finally, the state.

This explains my choice for an action-research method based on a participatory approach that, although proven effective since first applied in Scandinavia in the 1960s in the Norwegian Industrial Democracy Project, is not well accepted by some authors who understand that the change might actually be imposed by the ergonomist, which jeopardizes the democratic value of the intervention. For example, Dwyer (2000), considering the pessimistic results of Martins (1999), questions whether participatory management in Brazilian enterprises is a tool for worker participation or worker domination or, in more direct terms, whether it is a managerial strategy for worker manipulation. Dwyer also points out that Fensterseifer (1995) questions whether the workers are satisfied with participatory management, or do they have another more attractive proposal. Manufacturing industry participation has been viewed with suspicion by trade unions and work forces (Wilson, 1999), since workers involvement with management might turn them into experts, thereby threatening union solidarity while giving management access to shop-floor information. However, the very goal of ergonomics is to make the work environment a healthy and productive place, and the only way to achieve this is to change it in accordance with the personnel, technological, and work design subsystems, and by doing so along with the people who carry out the jobs. The participatory approach of a MA, together with its application in three Brazilian companies, is presented in Section 6.2.

6.2 Macroergonomic Work Analysis

MA (Guimarães, 2000) is a participatory approach to ergonomics which involves people in all phases of an ergonomic intervention: work analysis, problem evaluation, proposal of solutions, implementation of solutions, and evaluation of results. The fulfillment of

each phase depends on the approval of all participants (workers, supervisors, managers, board of directors), who must be aware of, and agree with, the goals and the method that will be used to reach them. MA assumes that ergonomics in an organization, whether in the private or public sector, should be under the responsibility of an ergonomics group, which, by being part of it, can better understand this complex "living being" organization. MA was designed to use both qualitative and quantitative data that are available because it makes it easier for people with different levels of knowledge of ergonomics to understand the proposals. Quantitative data, in particular, arouses the attention of managers and a board of directors and this has very often proved to be a key factor in a project being continued.

MA is primarily built on workers' job demands and considers six constructs related to a sociotechnical system, besides the workers' characteristics (the personnel subsystem): (1) the *physical* environment and (2) the workstation characteristics (part of the technical subsystem); (3) the *design* of work, (4) the risk involved in the task, and (5) the content of the task (the work design subsystem); (6) issues related to the *organizational culture*, its relationship with such aspects as the unions and the society itself, plus the affect of government legislation, regulations, and trades (the external environment subsystem).

The importance of relating ergonomics issues to the sociotechnical subsystems is because it provides the opportunity to better understand the constraints that influence the system in focus. Hendrick and Kleiner (2001) proposed four subsystems as the components of a sociotechnical system:

- The personnel subsystem, which comprises the characteristics of the workforce such as professionalism, demographic characteristics, and psychosocial aspects.
- The technological subsystem, which consists of the physical environment and the characteristics of the workstation, including machinery, tools, equipment, and degree of automation.
- The organizational/work design subsystem, which refers to the design of an organization's work system structure in terms of its complexity, formalization, and centralization. (In MA, the work design subsystem is not related directly to the organization, but immediately to the type of work design, although Hendrick and Kleiner (2001) deem this to be work design technology in the technological subsystem.)
- The external environment subsystem which affects organizational functioning. This basically consists of five types of environments: socioeconomic, educational, political, cultural, and legal.

The subsystems are interconnected (or more precisely, the work system should be designed to suit both the personnel and the technological subsystems), but it is possible to say that the first three subsystems are primarily influenced by the external environment. This is particularly true in Brazil, because of all the external forces which keep the country in a situation of almost total external dependency.

The following sections describe three cases of ergonomic intervention in medium-sized (100–499 employees) and large (more than 500 employees) companies in the south of Brazil, each of which is a representative of the most important industrial sectors of the southern economy, namely electrical, automotive, and shoe manufacturing. Each was also representative of one of the three reasons for starting an ergonomics program:

- The company has to comply with the demands of the Ministry of Labor.
- The company wants to comply with international standards to be more competitive.
- The company is interested in benchmarking a work system that reduces the level of injuries to workers and increases productivity.

Despite differences among the three companies, their prime interest was to reduce osteomuscular injuries because none of the companies knew that ergonomics also dealt with production demands. After explaining that, good ergonomics can also mean good economics (Hendrick, 1996), proposals were drawn up according to a macroergonomic viewpoint: focused on designing a production system according to both human (personnel, which includes social and/or personal) and production (technical and work design) needs, i.e., increasing satisfaction and reducing injuries, along with increasing productivity and reducing material losses. The proposed intervention in the three companies was based on the ideas of the sociotechnical approach of the Tavistock Group, as applied at the automotive Volvo plants at Kalmar and Udevalla, in Sweden (Berggren, 1992), but it also considered the importance of introducing clear procedures as prescribed by the Japanese lean system (an important contribution that Berggren (1992) noted was missing in the Swedish approach). The three "lean sociotechnical" projects considered the personnel, technological, and work design subsystems as well as the external environmental characteristics of the organizations. All basic phases of an ergonomics intervention (i.e., work analysis, evaluating the problem, proposed solutions, implementing solutions, evaluating results) were carried out at the three companies, with the MA method being applied by the same team from the Laboratory for Process and Product Optimization (LOPP)/Design, Ergonomics and Safety Group (NDES) of the Graduate Program in Industrial Engineering (PPGEP) of the Federal University of Rio Grande do Sul (UFRGS).

6.2.1 Case 1: When a Company Has to Comply with the Demands of the Ministry of Labor: An Electricity Meter Manufacturing Company

The Electricity Meter Manufacturing (EMM) company is the world's most important group dealing with energy engineering. This Swiss–Swedish company comprises 1,300 companies in 143 countries employing 200,000 people. Between 1997 and 1999, the EMM medium-sized plant (then with 300 workers) in east Rio Grande do Sul, together with LOPP/NDES, developed an ergonomics program in the electricity meter assembly plant (Guimarães et al., 2000a). EMM was interested in reducing the incidence of osteomuscular problems which was too high according to the Ministry of Labor, and it also had a very high staff turnover with 36% of staff having less than eight months' service in the company. Workers in the assembly line considered osteomuscular disorders as the most serious problem, these affecting mainly hands, arms, shoulders, and the back. They pointed out the difficulty in handling the product during assembly and the intense work rhythm. However, in addition to these problems, EMM was having a hard time in keeping up with both the Takt time (daily production number required to meet orders in hand divided into the number of working hours in the day) and the quality of the meters produced. Workers and managers were invited to participate in all phases of the project, but unlike the workers, managers did not engage themselves in the design of workstations, the environment, and the organization of work. The EMM product development team helped to redesign the electricity meter to make it easier to assemble and repair.

In order to access the benefits of each modification implemented, the different phases of the ergonomics intervention, Phases 2–4 (i.e., P2–P4) were compared to the starting point, Phase 1 (P1). Variables under consideration were the workers' health and productivity. However, because data on workers' health were not precise (due to the lack of detailed information from the health department), only productivity was fully analyzed. At the starting point (P1), EMM was a very Taylorist/Fordist traditional type of assembly line, comprising 10 workstations (one worker at each workstation), each of the 10 workers being responsible for a small part of the total assembly work. The tasks (which basically involved handling, screwing, adjusting, and fitting small components) were conducted in a mean cycle time of 0.9 min (minimum 0.73 min to maximum 1.07 min depending on the workstation and/or worker). Based on the videos taken from the workers during the workday, the type and order of execution of the movements and the time spent on them were evaluated according to kinesiology concepts (Kapandji, 1982) and some rules of ergonomics on fine motor and precision work (Grandjean, 1981). This kinesiological analysis showed that the work was repetitive and stressful for the hands, arms, back, neck, and shoulders. Workers have to twist their hands to support the meter while using the screwdriver. Assembly demanded the use of many screws and small pieces. At the end of the line, the meter could weigh up to 4 kg, and was too heavy to manipulate. According to the workers, the rhythm of work was too intense, leaving no time for rest pauses. The working day lasted 8 h, but overtime work of 1.5 h per day was very common in order to compensate for imbalances in daily production.

At P2, the company started a 10 min physical exercise program, during the working day. The LOPP/NDES team did not prescribe the exercise program as a palliative for work injuries but did not intervene when the program was implemented. P3 corresponded to a period when the physical exercise program was already running and major changes were made to improve environmental conditions in terms of temperature, noise, and illumination in the plant, all of which were set at comfort levels. Thermal comfort was obtained by artificially controlling the temperature to around 23°C (73°F). Acoustic plates were used under the ceiling to reduce noise. Environmental music was also introduced. Illumination was enhanced considering the amount and type of light needed for each workstation. Barriers (walls and partitions) between sections in the plant were eliminated in order to promote integration of assembly, calibration, and finishing sections. Integration was imperative for future major changes in the organization of work, which took place in P4.

P4 was the period of the most dramatic changes: workstations were designed to favor multitask work (i.e., they supported a cellular work organization), posture alternations (from seated to standing positions) and the *modus operandi* of each worker. Despite the importance of having a prescribed procedure, to organize and coordinate tasks and especially to facilitate the training of new employees, Pastre (2001) showed that the meters were not assembled in the same way by different operators. Therefore, the concept of cells took into consideration the enrichment and autonomy of the worker's task, not just by making the job more dynamic, but also allowing scope for individual differences. From a cognitive point of view, the cells were designed to make each worker responsible for the accuracy of assembly and production time, and from a physical point of view, the workstations were designed so all components and tools were within the worker's reach. The working area was under the 5th percentile anthropometric reach. All materials (components, equipment, tools) were organized according to the sequence of assembly. Linear and partial work was replaced by a cellular format of work organization and all tasks (done by 10 workers, on average), in the line, were then done as follows:

- In a unique cell, operated by one worker, in the case of the monophasic (simpler) meter, in an average assembly time of 4.5 min. In the manufacturing cell of monophasic meters, each worker is responsible for assembling and precalibrating a whole meter instead of being responsible only for a part of it (as used to be in the traditional line system). At the end of the project, there were nine cells for assembling and calibrating the monophasic meters, and each of the nine workers was responsible for personal control of own time as well as the quality of the product.
- In a cell comprising three workstations, meaning three workers per cell in the case of the more complex meters. The polyphasic meter is bigger and more complex to assemble than the monophasic, and therefore its manufacturing (assembly and precalibration) cell consisted of three workstations operated by three workers who rotate among the three workstations during the working day. Therefore, as in the case of the monophasic cell, the workers were trained for multifunctionality, each of the three workers in a cell taking turns in all three workstations/cell. The nine workers in the three cells were the same as those who worked in the original assembly line. The 10th worker from the assembly line acted as a "wild card" for the three cells. The mean cycle time in each workstation/cell was 3 min because each worker was then responsible for 10 operations (instead of the three operations in the line). The same principle of leaving components within the subject's reach was applied to the design of each of the three workstations.

Therefore, there was no longer the "one-man, one-workstation, one-task" Taylorist/Fordist paradigm. Because the workers operated in a much wider cycle time and were able to work at any workstation in a cell, there was less chance of their incurring injuries resulting from repetitive movements. The most important factor was that they now have a broader work experience with the prospect of being able to work in other sections such as calibration (as studied by Krug, 2000) and meter finishing. Because they were trained to become multifunctional workers, they could look forward to a raise in salary in addition to work enrichment.

Besides the changes in the environmental conditions, the design of workstations and work, the designs of both monophasic and polyphasic meters were reviewed in order to make it easier to assemble and repair them. Changes in periods P3 and P4 were implemented according to the workers' and manager's priorities, and were established after a few months of discussion. Participation during all the phases of any ergonomics study is the major focus of the macroergonomic method used by LOPP/NDES. The incidence of upper limb disorders dropped significantly (about 70%) after the ergonomics intervention. Comparing the results from the interviews and questionnaires before and after the intervention, subjects reported less fatigue and pain after working in the cell which made it clear that both dynamic work and balanced rhythm contribute to reducing osteomuscular injuries.

Analysis of detailed data on productivity (Fischer, 2000; Guimarães et al., 2000b) showed a significant increase between 1997 and 1999, mainly when cellular work organization replaced the traditional assembly line. Productivity was defined as the number of meters produced per day divided by the number of hours worked. For all polyphasic models (it was not possible to evaluate productivity of the monophasic meters), productivity did not increase with physical exercise: there was no difference in productivity comparing P2 and P1. Also, there was no significant statistical difference in productivity ($F = 1.46$; $P = 0.20$)

depending on the ergonomic intervention period (P1, P2, P3, and the three assembly cells, C1, C2, and C3) for the most complex model. However, there was a significant difference in productivity ($F = 61.76$; $P = 0.00$) for the simplest model depending on the ergonomics intervention period. Productivity showed a particularly large improvement (up to 17%) in the cellular system assembly, while there was no difference in productivity comparing P2 and P1. One possible explanation for the fact that the influence of the cellular system on productivity is not as large for a more complex assembly model is that complexity of assembly diminishes the effect of work organization. I now understand that the efficiency evaluation method based on number of products per period of time was deemed too conservative and academic, because it did not account for other gains such as improved meter quality, reduction of material and components used in the process and in the product itself, and reduction of time spent on quality supervision of acquired components (a program with the suppliers guaranteed that only conformed material was delivered to EMM). All together, these gains add up to 147% efficiency assumed by EMM to be as a result of the ergonomics program.

According to Fischer (2000), workers liked the new cell system which they helped to implement, confirming that participation in the project made changes easier to accept. Workers considered the ergonomics changes as a benefit for their health and work motivation. The board of directors was pleasantly surprised at the additional financial profit due to ergonomics and decided to proceed with the ergonomics program in a more intensive way. Taking the financial benefits, in addition to the human well-being, into account proved to be an effective way to persuade a company to spend on ergonomics. However, after the third year of project, LOPP/NDES did not form an ergonomics group in the company and the program stopped when ergonomics fell under the responsibility of the Human Resources Department and was no longer linked to the Production Department. EMM was the first example that showed ergonomics can only be effective if everyone in the entire company is involved in the program, which was not the case with them. The workers and the CEO were interested, but not the management and supervisory levels of the company. An explanation for this might be that the former foresee the gains (i.e., empowerment and financial return through increments in productivity, respectively) while the latter get neither the intangible nor the tangible benefits of it.

6.2.2 Case 2: When a Company Wants to Commit Itself to International Standards to Be More Competitive: The Case of the Farm Equipment Company

The farm equipment (FE) company is the world's leading manufacturer of FEs, with plants in 16 countries employing approximately 50,000 people around the world. In Brazil, there are four FE sites, one of them (where this research was carried out) in northwest Rio Grande do Sul. This FE site represents a large American company with more than 1,500 workers in its three plants: the harvester plant, the tractor plant, and the platforms plant, producing, on average, 50,000 harvesters and 30,000 tractors per year. The partnership between LOPP/NDES and the FE company started in 1999, when LOPP/NDES trained and formed the ergonomics group of the company, which was part Brazilian and part American at that time. The ergonomics group, after being trained in ergonomics, is supposed to share the training with all workers, in order to identify everyday problems, propose solutions, and implement them with the assistance of LOPP/NDES. Many courses, attended by frontline workers, supervisor, and management, were held to create the same ergonomics language in the company. During the last nine years, using data from the Safety and

Health Department, and the support of the ergonomics group and workers, many ergonomics interventions based on MA have been carried out, resulting in improvements as reported in the paintshop (Portich, 2001), metal working (Kmita, 2003), and welding (Silva, 2003; Silva and Guimarães, 2006) departments. Basically, changes focused on enhancing the safety of all machines and tools, environmental comfort (such as noise reduction by removing noise at source), improving automated systems for the handling of material, better layout that facilitates movement of both people and material, and a modification of workstations which allowed workers to reach their work with less muscular stress.

In 2004, MA was also used as the ergonomics basis to be implemented along with a lean production system adapted from the Japanese lean system (Shingo, 1981; Ohno, 1988), called demand flow technology (DFT) (Costanza, 1996). The DFT system is based on the assembly of subsets (i.e., the assembly of small parts that will configure a bigger set) with multifunctional workers operating in a cell organization. Despite all the efforts of LOPP/NDES to define the ergonomics changes that must accompany the new production system, not all attempts to build a balanced system were fruitful, because the calculations for balancing production follow production demands more than the human capability for meeting them. In accordance with the Japanese "Lean" ideas for fulfilling production quotas, which often require an extreme speed of work to cope with the pace of a very tightly coupled system, workers had to work overtime. The new lean system also resulted in highly regimented work, in a way that was very often beyond the workers' comprehension. Although the work became richer than it was under the traditional Taylorist line, workers complained about the little time allowed for carrying out all the tasks to assembly the prescribed subsets, at the pace demanded by the Takt time. As reported by Ferreira (2006), the new production system brought good (i.e., a more organized and safer plant) and bad (i.e., a more demanding work system) changes that are still being adjusted in order to accommodate human capabilities and requirements.

Despite the nine years of partnership and so many interventions in different sectors of the FE northwest plant, it was not possible to really measure the costs and benefits of ergonomics, due to the size of transformations all happening at the same time, in different sectors of a very large plant. Besides the changes promoted in the plant, it is important to note that not all goals could be achieved. However, it was only at FE/northwest that MA was fully implemented as idealized, i.e., an ergonomics group working with LOPP/NDES and everyone in the company understanding and willing to attend to the goals of ergonomics. One of the reasons for achieving this was the fact that FE has a very strong ergonomics program for all its plants in 16 countries around the world. Every year, all plants send a report to the head office in the United States, and the report is evaluated by a consultant who also visits all sites. The commitment to International standards is a very strong reason for the board of directors to keep ergonomics as a priority. As a consequence, the Health and Safety Group as well as the ergonomics group depends on LOPP/NDES to maintain the good performance of the ergonomics program. The most important pressure is therefore the company's own standards.

6.2.3 Case 3: When a Company Is Interested in Benchmarking a Work System That Reduces Workers' Injury Levels and Increases Productivity: The Case of a Shoe Manufacturer

Brazil is the third largest shoe manufacturer (SM) in the world (after China and India), and produces more than 700 million pairs of shoes per year, mainly for the North American

market. Despite this, its manufacturing system is not as modern as its marketing system: production is highly dependent on human labor using both traditional equipment and a traditional organization of work. Shoe manufacturing in Brazil is, traditionally, a typical Taylorist production system: each worker is in a specific workstation all day long, doing a job that is a very small part of the whole process, and therefore is responsible for a very small part of the product. This type of work organization is known to be physically and mentally harmful, leading to illness, injury, low productivity, and low product quality (Friedman, 1967; Dejours, 1980; Grandjean, 1981; Braverman, 1998). A literature review on the shoe manufacturing system in the state of Rio Grande do Sul, considered the most important site in Brazil, showed that both worker qualification (Piccinini, 1990; Prochnick, 1992) and productivity (Piccinini, 1990) are low and the level of injuries is high (Renner, 2002) in most plants, which is a disadvantage for the social and safety system and the competitiveness of Brazilian shoe manufacturing. According to Mody et al. (1991), Brazilian competitiveness relies solely upon the low price of the products obtained because of the industry's low salaries.

In order to start changing this picture, an SM in north Rio Grande do Sul, Brazil developed a partnership with the LOPP/NDES for a three year macroergonomic research project. The motivation of the company's industrial director for engaging in a project as ambitious as this was twofold:

1. Interest of the industrial director and his consultant in turning the company's production system into the benchmark of more state-of-the-art shoe manufacturing (which is good for the company's image).
2. Opportunity of carrying out an ergonomics project (which is also good for the company's image) at no financial cost, since the project was sponsored by a grant from FAPERGS (a research foundation of the state of Rio Grande do Sul).

Although a large company (one of the six largest SMs in Brazil, employing more than 1000 people), producing more than eight million pairs a year and exporting more than 30% to 100 countries, the company is run by a family, like almost all the other SMs in Brazil. The level of technology is low (using simple sewing machines and knives) as is the work design (a very Taylorist system of "one man, one task, one workstation" during the whole working day). As a consequence of the monotonous and repetitive work, the level of musculoskeletal injuries was very high. External characteristics impacting on the results of any investigation were the wide variety of manufactured shoes that have to be produced in very short cycles, depending on a very irregular demand (mainly from the United States and Europe) since sales depend on the situation of the international market. To override such problems, enlarge and enrich the job and cope with product diversification, a new type of work organization, following the sociotechnical model, was prototyped. Ninety-seven workers were trained to work in all workstations manufacturing any type of shoe at any time. The workers organized themselves to work in teams, being responsible for the quality of both the production and products of their cells. The quality of the shoes could be controlled because the workers were trained according to comprehensive procedures that incorporate quality control. Despite the traditional belief that it is very difficult to train people to work in many workstations doing different tasks, the learning curve showed that they were able to learn all tasks in less than a month. At the end of four months, workers had complete control of up to 20 operations. Many workers set their own goal to control all 115 operations that some types of shoe require.

Another major change was in the length of the working day. When the project started, working hours at the company were from 05:00 to 14:48 for the early shift, and from 14:48 to 00:17 for the late shift. However, working hours which are not synchronized with human biorhythms, especially when this disrupts a night's sleep (see Folkart et al., 1985), end up causing health problems as well as productivity ones. The highest peak of accidents was at 6 am, probably because people were not yet fully awake or feeling fatigued as a result of getting up so early in order to leave home between 03:00 and 04:00. After many discussions with the workers and managers, working hours were changed to 06:30–17:15 Monday to Thursday and 06:30–11:30 on Fridays, on a trial basis. Workers did not adapt well at first because domestic life also had to change, and it was not easy to get a daycare center for the children although Brazilian laws state that the company has to facilitate daycare services when it has more than 30 female employees nursing their babies. Unfortunately, a place for children to stay while their parents are working is still a problem to be solved in Brazil since there are no full-day public schools in the country. After three months experience of the new working hours, productivity rose and the company inaugurated a daycare center. The finally agreed working hours are now from 07:00 to 16:48 with lunch break from 11:30 to 13:00.

Renner (2007) found that, due to reducing the repetitive movements, and enriching tasks overall, complaints of fatigue, pain, and injuries reduced to zero at the end of 12 months of the project, and that the rate of absenteeism and accidents was around 80% less in comparison with other production lines operating in the traditional way. Because of team organization, the relationship among workers improved and they reported feeling more important, happier, and more satisfied with their work and colleagues. Because they had learnt many different tasks, they found this was the preparation for producing whatever new type of footwear easily and in a very short period of time, which enhanced the setup time of the cells. Product quality improved, and less than 10% of the shoes manufactured had to be repaired. There was a reduction of 45.7% in the total time of nonworking hours. Most important of all, the quality of the workers' skill improved, and as they stated, they have more value on the market now, since they know how to operate whatever machine or tool in order to produce whatever type of footwear.

At the end of the second year of the project, productivity had increased 3%, working hours had been rescheduled since a daycare was built to provide childcare while parents are at work, and the company had started to prepare more people to work in teams. One hierarchical level of management was eliminated because these teams are now able to carry on their jobs without close supervision. In addition to such improvements, this project has won three awards so far, all of which has made it clear that good ergonomics is good economics. Planning for the forthcoming years has included changes in work organization in the whole factory, a reduction in the turnover of workers by producing more for the internal market (therefore, being less dependent on the external market) and a reduction in environmental waste. Despite all the positive results, the owners still do not see the gains as clearly as both the industrial director and the workers have done. For the owners, the success brought the company into the spotlight which might be good for marketing, but might catch the attention of the Ministry of Labor which, according to them, is not good. The drive to carrying on with the project came from the director and a consultant, but the owners and middle/low management levels were never involved. The fact that the company did not pay for the project may be a reason why the directors did not value the project.

6.3 Lessons Learned from the Three Experiences

Table 6.1 shows, at a glance, the scenarios of the three cases. It is important to note that the three companies might be considered as market leaders in their segments and among most Brazilian companies.

6.3.1 Personnel Subsystem

The personnel subsystem is very similar in the three cases, the most important characteristics being the workers' low level of training and schooling. Only at the FE manufacturing company was the degree of professionalism higher and the company makes an effort to improve its employees' formal educational qualifications. However, the type of work being done at FE company is more complex than in the other two companies, since assembling subsets of a tractor, or a harvester is, of course, more demanding both cognitively and physically. Keeping the work force interested in their jobs is important as this can save money by avoiding high staff turnover, money which otherwise would be spent on hiring and training new workers. Because staff turnover is lower at the FE company, the workforce is also more confident about their jobs. The wages at FE are, as a consequence, higher in comparison with the other two companies. A common characteristic of the workers at the EMM company and at the SM is their fear of making errors and losing their jobs. As a consequence, because "what is new is prone to error," it was more difficult to persuade workers to get involved in the changes. Although the changes were more dramatic at the SM, it was completely up to the 97 workers who got involved in the project to keep the changes evolving. The shoe company did not understand that gains in the personnel subsystem would reflect on an overall gain, as happened at the FE manufacturing company.

Although there is no doubt that the provision of quality education has to improve in Brazil, the three cases presented (like others under study by LOPP/NDES) showed that a better type of work design (such as teamwork) is not dependent on educational attainment, but on the ability to develop both a sense of cooperation and of social collectivity among workers. It is up to management to provide stable conditions for group interactions, which is not a practice when the design of work is fragmented, as in Taylorism/Fordism. However, managers in most Brazilian industries understand that people are an available and inexpensive resource, and therefore easier and cheaper to substitute instead of investing in training. In the cases studied, old managerial practices, and not the level of schooling nor any other demographic characteristics, were the most important causes responsible for lowering the quality of the production system. Assuming that engineering sees human work as residual to be replaced by automation (Berggren, 1992), it is easy to understand how unimportant the personnel subsystem is for companies. To "solve" the personnel problem, administrators and engineers need to assign fewer workers and more technology to the production system, and increase the partitioning and control of human work. However, ignoring humans is not a wise approach for work design because humans are, and will always be the flexible part of any system, and will always be important for such things as designing, controlling, repairing, and assembling. Good ergonomics is helping organizations to enhance the personnel subsystem and to build a better sociotechnical system.

6.3.2 Technological Subsystem

At the EMM and the FE manufacturing companies, improvements were made to the technological subsystem, the physical environment, workstation characteristics, tools,

TABLE 6.1

Scenarios of the Three Cases of Macroergonomic Intervention in the South of Brazil

Company (Employees)	Sector	Origin	Demand	Technology	Personnel	Technological Changes	Work Design Changes	Support	Problems
Electrical meter manufacturing (300)	Electrical	Swiss–Swedish	Ministry of Labor	Medium	Low level of professionalism Low level of schooling	Substitution of line for cell: new workstations and layout Environmental comfort	From Taylorist to full cell: enlargement and enrichment	Board of directors	Managers
Farm equipment manufacturing (1700)	Auto	United States	International Standards	High	Medium level of professionalism Medium level of schooling	Substitution of line for cell: new workstations and layout Enhancement of the safety of machines and tools Automated systems for material handling Environmental comfort	From Taylorist to small cell: enlargement	Board of directors	Managers
Shoe manufacturer (1800)	Shoes	Brazil	Benchmark	Low	Low level of professionalism Low level of schooling		From Taylorist to full cell: enlargement and enrichment; empowerment: Improvement of quality of life Change of journey time Daycare center	Industrial Director	Managers Owners

equipment, and at the FE company, even to the degree of automation for making assembly safer, faster, and more reliable. Technological improvements at the SM were minimal (adding some chairs in order to alternate the work posture), because the physical characteristics of the plant left little space for changes. The company is now considering moving to a new site.

However, the technological subsystem was not the focus of the three cases, but rather the work design subsystem was, since in these situations it was the key to changing people's quality of life and proved to be the most important issue for reducing injuries and enhancing productivity in the three cases. Work design is probably not the focus of most managers in different industrial sectors who, as mentioned by Berggren (1992), understand that technology is the key to success while people on the job are the problem. Besides, it is important to note that although the technological subsystem involves financial cost, it is easier to promote improvements in this subsystem than in the work design, which does not incur additional costs, but imposes a more difficult and expensive change: change in a company's culture. Technology is not superior in flexible systems which depend on the skills and versatility of human work, therefore enhancement of both personnel and work design subsystems are crucial for the development of production systems in Third World countries.

6.3.3 Work Design Subsystem

In the three cases reported, the production system was very traditional, leaving no room for job enrichment, empowerment, or autonomy. Traditional work meant fragmented, very centralized controlled, individual work, which is in accordance with Taylor and Ford's outmoded idea that workers are supposed to contribute only by using their physical strength while supervisors and managers do the thinking. Therefore, the change to more collective, multifunctional, cellular work was difficult to promote because the roots of the traditional line were very deep. Each company's culture was based on the assumption that their workforces was not able to think for themselves, and therefore had to be controlled by the hour (or even by the minute). After implementing the new systems, in all three cases, it was clear from the responses of the workers that the work enrichment, obtained by enhancement of knowledge, autonomy and involvement, is a major factor in work satisfaction.

The full cells for manufacturing the monophasic meters at the EMM company cannot be considered as collective work since each worker was responsible for a whole product and each had an individual goal to meet. The cell operated by three workers for manufacturing the polyphasic meter had a more collective characteristic. In both situations, the cells gave back the control of the whole product to the workers and with it the autonomy to produce in their own rhythm rather than at the pace of a line.

At the FE manufacturing company, collective teamwork was implemented, although to a lesser extent in comparison with the collective work in the SM, because the cell model was Toyota's lean production system, not the Volvo sociotechnical one. To minimize the overload effect characteristic of lean production, the LOPP/NDES group helped the industrial engineers to balance the workload imposed by the cells, and showed them that the idea of people working together to meet a goal is more important than individual work, controlled by the minute. Engineers even agreed to discuss the way that production control would take place, and after LOPP/NDES proposed that tractors and harvesters should not be built per minute or per hour, they agreed to testing production control based on longer periods of time, more compatible with the assembly of the sets being produced in the cells. It is important to note that the FE company was the most prepared to accept the

largest changes. It is argued that the fact that the ergonomics group and LOPP/NDES were not more successful was due to the levels of complexity, formalization, and centralization which were greater at the FE manufacturing than in the other companies.

Collective work, or teamwork, was possible at the SM, and showed that it really works. Even with a personnel subsystem characterized by low levels both of schooling and professionalism, teamwork made it clear that workers do not need close supervision, only orientation. But this was a problem for the supervisors because they were not comfortable with delivering orientation, since they have been trained to give rulings, and to ensure procedures were followed without being questioned. Although the impact of collective work was not deeply evaluated in the three cases, it seems that the sense of completing the whole job (or big sets) instead of small parts of it, and of being responsible for the quality of the product, was the most important issue for the workers. Workers reported that knowing more, doing more, and being able to make decisions in their jobs were the best part of the new system, because they got more satisfaction from this and also felt less tired. The explanation for this might be the fact that lesser external control and pressure plus the autonomy to do the job at one's own pace helps balance the everyday workload and gives back the autonomy that supervisors take away in the traditional system.

It is a shame that so many innovative ideas are kept locked up in each individual's mind working on the traditional production lines. People, no matter whether their "collars" are blue, or white, are the flexible part of production and the key to enhancing the quality of the work they perform. Workers in the cellular multifunctional system were very happy to learn more, and to receive more autonomy because of teamwork. However, managers and especially the supervisors were not as happy, because they perceived that macroergonomics changes the procedures and affects the prescribed work they are supposed to supervise. A negative reaction to teamwork and empowerment was particularly evident with the supervisors of the SM. Due to the speed at which the workers learned the different tasks, and how quickly the teams learned to rearrange themselves to rotate among the different workstations, the supervisors clearly noticed that they, as supervisors, were not needed in the new organization, and tried to impede the proper working of things in order to make themselves needed, and therefore to keep their jobs. They could not foresee that they could have a new role, as mentors and coordinators, in the same company. Of course, they too would have to be trained to assume this new role.

It might seem that it was a bit too much to apply, in a Third World country like Brazil, the very advanced ideas of a production system that were applied in a social democratic society like Sweden. Although the teamwork system was difficult to implement, and despite all the pressure the supervisors brought against the idea, it proved itself to be suitable to any society, thus demonstrating that the sociotechnical approach suits human beings, no matter how advanced or otherwise the societies they belong to are. Trist et al. (1963) and Berggren (1992) made it clear that work design is actually a matter of choice, that there is mutual interdependence between organizational development and the technical design of production and, therefore, work design can be shaped independently of technological conditions and of the type of process and product under production. The three cases presented also confirm that work design is a matter of choice, and it can improve both production and the quality of people's lives. Even the low level of schooling and professionalism of the companies' personnel subsystems did not impair teamwork or complete assembly concept, showing that, with clear procedures, a better work system can be built in companies today, while the government will hopefully improve Brazil's educational system in the future.

6.3.4 External Environment Subsystem

The MA approach was used in small, medium, and large companies in the south of Brazil, and despite differences due to their size, personnel, and technological levels, one fact, common to all companies, was the external environment subsystem which was the key to the success or failure of the ergonomics program. The reason for this is clear: as is common in a developing country, most large and medium companies are multinational, and Brazilian sites are supposed to follow the rules of the head offices although the conditions on these sites are not as good as at the head office. Neither the personnel nor technological subsystems in the Brazilian subsidiaries are of the highest standards as the personnel have a lower level of schooling, and the technology used is not the best in terms of efficiency and safety. As a consequence of the low level of education in Brazil, jobs are designed for both low levels of technology and personnel subsystems. The tasks are poorly designed (i.e., people are allocated to just one workstation, doing highly specialized repetitive work characteristic of large-scale production systems, and no involvement or contribution is expected from them), productivity is low, while fatigue and dissatisfaction are high. Because managers assume that ergonomics is just a matter of defining chairs and tables, work design is not supposed to be addressed (actually, managers do not like interference in the production level) and no gains are expected as an outcome of the intervention. This cycle is difficult to break since "no gain" is the catch-phrase for interrupting the ergonomics program.

Outdated Brazilian laws, the lack of trade union strength, and lack of government interest in building a better industrial structure in the country are also elements of the external environment subsystem that make it difficult for ergonomics to get stronger in Brazil. For example, it is very difficult to hire people for part-time jobs in Brazil, which makes the company rely on extra hours to compensate for under production and these extra hours diminish the effects of the balanced workload obtained by the collective or cell-work system. Unions do not interfere in this matter and spend more time discussing raises in salary. However, money is not necessarily the most important issue for the workers (although they do not earn much): in almost all projects carried out by LOPP/NDES, a fair job and a just salary policy are more important than the money itself. The workers seldom talk about their unions and, in the case of the SM, the workers pointed out that they get stressed from the pressure they come under from their own union. The experience showed that unions have to be more involved with the managerial practices fighting for a more human-centered work design rather than acquiescing in regressive Taylorist or Japanese lean systems just because the workers have a job and get paid.

The reported cases showed that improvement in work design was the key for enhancing the whole sociotechnical system. Despite all the odds and the difficulties faced when implementing work design changes, it was worth fighting for human-related improvements in the first place rather than for technological ones. As long it is safe, technology, no matter how sophisticated, cannot be assumed as more important than humans, mainly in flexible systems which depend on the skills and versatility of human work, as happens to be a common case in the country. Actually, looking more carefully to the technological, personnel and work design conditions in the majority of Brazilian enterprises, it would be unexpected to get the levels of production that makes the country, according to the 2005 International Comparison Program (ICP) report on the Purchasing Power Parities (PPP) of the World Bank (2008), the sixth economy of the world, accounting for 3% of the World's GDP along with the United Kingdom, France, Russia, and Italy. Such performance is in part a reflection of the high levels of creativity and adaptation (in other words, resilience) of the Brazilian population, which is well-known worldwide through the music, dance,

food, and arts. In the work domain, these characteristics of resilience compensate for the low level of education and professionalism of the personnel subsystem, making it possible for the workers to bypass all sorts of problems they face in the workday in order to keep the best productivity and safety levels they can reach under the circumstances. Although this resilient behavior might help the enhancement of productivity, workers are not recognized (either by the entrepreneurs or the government) for this relative success of the production system, and what is worse, the system does not evolve toward a more organized, better equipped, just and safer environment.

Despite its poor condition, the human subsystem stands out due to its resilience, and the experience showed that better work design was the key to changing people's quality of life and it proved to be the most important issue for reducing injuries and enhancing people's professionalism and self-esteem in the three cases, along with productivity. Besides, it is important to note that work design improvement is financially cheaper, although culturally more expensive to apply. Therefore, assuming that technology in use is safe even when it is simple, it is fair to assume that technological sophistication is not the major issue for solving the lack of economical and social development in Brazil; however, enhancement of both personnel and work design subsystems is crucial for the development of more productive and safer sociotechnical systems in Third World countries.

6.3.5 Costs and Benefits

In all three companies, the board of directors did not expect ergonomics to be more than "traditional"; they (the company as a whole) had the perception that the goal of ergonomics is to adjust the workstation in order to reduce osteomuscular injuries, and there were no expectations in relation to production gains. However, the impact of the interventions did enhance the workers' quality of life, together with improved productivity.

Due to the conditions of the companies in relation to the sociotechnical system differing significantly, and the diversity in their goals, the results from the interventions also differed. Basically, the results during and after implementation were very different due to the expectations of each company and the degree of engagement of people in the ergonomics process. The benefits measured at the EMM company (70% reduction in injuries and 17% increase in productivity) and at the SM (80% reduction in absenteeism and accidents, 45.7% reduction in the total of nonworking hours, 3% increase in productivity) were in accordance with those reported in the literature by Nagamachi and Imada (1992), Rooney et al. (1993), Hendrick (1996), and Nagamachi (1996). After the implementation of a macroergonomics program in a petroleum distribution company, Nagamachi and Imada (1992) reported the following reductions: injuries by 54%, motor vehicle accidents by 51%, off-the-job injuries by 84%, and lost work days by 94%. While Rooney et al. (1993) reported a 70% reduction in lost-time accidents within a two-year period in both the production and distribution divisions of a clothing company.

The fact that ergonomic benefits could only be measured at the EMM company and the SM was due to the size of the companies. In these two companies the LOPP/NDES team could access and compile all data available in the production and safety and health departments. But as the FE manufacturing plant was more complex, with many departments, divisions, and sectors, manufacturing different products like harvesters, tractors, and planting machines, it was very difficult to track all the costs and benefits from the many different divisions. The Health and Safety Group as well as the ergonomics group of the FE manufacturer was not organized to get and compile the necessary data. This is an activity scheduled for the near future.

Although we could not achieve all the expected results, we did more in these three cases than we could do in other companies. Brazil still has a very long way to go with ergonomics in order to start ergonomics programs in micro (up to 19 employees), small (from 20 to 99 employees), and medium companies (from 100 to 499 employees) which account for more than 99% of the industries (and 67% of formal employment) in the country (IBGE, 2007). It is a good achievement though, that these three cases clearly demonstrated that ergonomics can bring about some progress in the underdeveloped sites in Brazil.

6.4 General Conclusion about MA, the Sociotechnical Approach and the Three Cases

These few successful cases show that it is possible to meet the goals of macroergonomics in Brazil: at a Swiss–Swedish electricity meter manufacturer medium size company, at a large, American company that manufactures FE, and at a large Brazilian SM, MA was used to elicit the problems of the four sociotechnical subsystems, and changes were made to enhance both the people's quality of life and productivity. The major impact on people's lives and the production system arose from work design enrichment derived from an adaptation of the lean sociotechnical model. The changes in work design (that were inspired in the Volvo sociotechnical approach with clear procedures as proposed by the Japanese lean system) imposed changes on all the other subsystems, making it clear how systematic ergonomics is and how powerful it can be as a tool for enhancing the quality of both production and people's lives. From the three cases, participation stood out: workers loved to be involved and always behaved cooperatively and enthusiastically. In all these projects, as well as in all other projects we have developed, the engagement with the workers was both a social and ergonomics learning experience. They were always keen to share their practical knowledge and responded very easily to our formal one.

In all cases, it was possible to note that workers' participation in the ergonomics program determined its continuation. When the board of directors bought the project idea, they did not impose any obstacle to its continuation, but buying into an idea does not necessarily mean financially. The SM was the only company that did not pay for the project (the government did) and the only company whose owners did not "buy into" ergonomics. In all three cases, the middle management level proved to be the real problem: they do not want, do not help with, and do not care about improvements. Their job is to keep the company running, no matter how. And this is true not only for the production managers, but also for human resources, safety, and health teams. This weakness in the personnel subsystem might be the very one that makes the Brazilian production system less competitive. How does one overcome this? One idea is to improve the undergraduate teaching of engineers, medical doctors, and administrators as well as health and safety technicians, and to include a module on the basic principles of ergonomics in their courses. The courses do not prepare these professionals to interact with people on their jobs. Therefore, the quality of education is a major obstacle to the development of Brazil in many sectors and unfortunately, it is also dependent on a dramatic change in the greater external environment.

The three cases presented were exceptions in the history of the LOPP/NDES group in the sense that it was possible to make a change and to evaluate the costs and benefits of the ergonomics intervention. LOPP/NDES has carried out many other studies that have not

left room for improvements and evaluation. It is possible to say that, in general, Brazilian companies are not prepared to understand the value of ergonomics and therefore do not expect it to bring any benefit to their organizations. However, change is a matter of choice and opportunity, and it is clear that ergonomists can help to show the way to make Brazil a better place for people to live in.

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7

Ergonomics Education in Industrially Developing Countries

Emma-Christin Lönnroth

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7.1 Introduction

The world is becoming knowledge based as progressive countries invest in education for the entire population, recognizing that the key to any further development is education. The major problem in industrially developing countries (IDCs) is a shortage of educated people. This is due to many factors, such as lack of compulsory education for children, low incomes (families who augment their income from child labor cannot afford to send their children to school), and a shortage of schools and teachers in some remote places. Further, there are places in IDCs where education is seen as appropriate only for boys, and where girls may even be actively prevented from going to school. In this milieu, few students have the opportunity to attend universities due to high costs and a scarcity of institutions of higher learning.

Industrialization brought with it new problems culminating in a high frequency of accidents and injuries at the workplace. In time, the trade unions fought for better working conditions and better work environments for their members, and safety laws and regulations were developed. Later, due to high absenteeism and compensation claims by employees, even managers became motivated to create safer work environments. The human-centered approach of ergonomics, aimed at creating safe working conditions and promoting workers' health, became an important subject. Over the past 50 years many methods, tools, and

procedures have added to a growing ergonomics knowledge-base which is now available for IDCs to make use of and adjust according to their own needs and conditions. Also, an increasing number of educational and training courses and programs in ergonomics have become available in industrialized countries. However, the situation in IDCs is very different.

Given a scarcity, and often unreliability, of data on occupational diseases, injuries and accidents in developing countries, there is a low level of awareness among decision makers about the importance of ergonomics in IDCs. Thus, few laws and regulations are developed to protect the workforce. In addition, there is a shortage of trained safety inspectors, and the few there are have little authority to intervene. At a government level, lack of awareness about the benefit of ergonomics means that it is not prioritized during the planning of educational courses and programs. As a result, there are few trained ergonomists to assess prevailing working conditions and provide solutions for improvements. There is also little focus or debate in IDCs about ergonomics at the factory level, at school or in the home, which results in a lack of knowledge and awareness of ergonomics at both the individual level and among the public at large. Thus, organizations such as labor unions have not focused on demanding ergonomics as a means of achieving better working conditions.

Cultural factors in general exert a strong influence on the recognition of the importance of ergonomics. Difficulties in accepting and adopting new technology and knowledge, an often fatalistic view of life and acceptance of destiny with no possibility of influence and improvements, are typically encountered issues in IDCs. Initial resistance to changing traditional methods of working and a short-term view of life (concentrating mostly on survival rather than on planning for the future) are other examples. Additionally, denial (with a simply "block-out") is a standby defense mechanism among people under pressure. The scarcity of resources in IDCs and the myriad of problems are so prevalent and so overwhelming that only the most visible among them, such as a lack of food, shelter, and clean water, and the need for treating of infectious diseases, are prioritized. Further, given endemic high unemployment rates, creating safe working environments and promoting workers' health are not prioritized because injured or sick workers are easily replaced. In such scenarios, ergonomics is often seen as a luxury appropriate only for industrialized countries which have managed to solve many of the basic living problems.

Rapid advancements in technology, business and market developments, and the trend toward knowledge-intensive activities make increasing demands on companies to optimally use their resources and to keep up-to-date with advances in science and technology. Yet human operators are the most valuable resource for any company to progress. Giving health, safety, and worker satisfaction, the highest priority assures motivated and committed employees and a good working environment. Engaging employees and improving their knowledge and skill at correctly analyzing their working conditions and developing new ideas and strategies for problem solving and practical improvement are essential for success.

Most courses and programs in ergonomics are offered at universities in industrialized countries such as the United States, the United Kingdom, and Europe. In IDCs, however, only a limited number of courses are available, e.g., in China, India, South Africa, and the Philippines. Additionally, courses in developed countries are not easily accessible for students from developing countries due to high costs and political hindrance. Exacerbating this problem is the fact that even if they get access to studying ergonomics abroad, few students return to their own countries, resulting in a brain drain. To create awareness and provide access to ergonomics education and training for people from IDCs, the Centre of Ergonomics of Developing Countries (CEDC) in Sweden has carried out teaching and

training workshops since 1983, www.cedc.info (CEDC, 2008). Many thousands, mainly representing those working at government and management level, but also representatives from educational institutes, health professions, and design and development engineers, have participated. People from Botswana, China, Colombia, Costa Rica, Cuba, Indonesia, India, Iran, Lithuania, Malaysia, Mexico, Poland, Sri Lanka, Swaziland, Sweden, South Africa, Taiwan, Tanzania, Thailand, the Philippines, Turkey, and Vietnam have received ergonomics education and training in various kinds of workshops through the CEDC.

7.2 Ergonomics Training Workshops

Teaching and training of practical subjects in workshops has been shown by many to be more effective than classroom teaching. A workshop is a type of action-learning in which all participants are actively engaged in the provided activities. "Action learning" was first developed by the experimental physicist professor Reginald Revans (1980) who found that conventional instructional methods were largely ineffective. He pointed out that people had to be aware of their lack of relevant knowledge and prepared to explore gaps in their knowledge via suitable questions and the help of others in similar positions. Revans described learning thus: L = P + Q where L is learning, P is traditional knowledge, and Q is questioning to create insight. The four major questions are Where? Who? When? and What? With three additionally minor questions Why? How many? and How much? Revans showed that real learning occurs when people learn "with and from others." As a result, on average the retained information from workshop practice is 80%, compared to reading 10%, listening 30%, and multimedia instruction 50%.

Thus, the CEDC has focused on providing an awareness of ergonomics in the form of workshops. Our workshops have focused not only on basic ergonomics but also on workstation design, evaluation of work environment conditions and provision of locally feasible solutions, reduction of musculoskeletal problems, and worker participation. Diverse ergonomics methods have been introduced and participants have been trained to use them in practice. Top and middle managers have participated in workshops aiming to develop vision and goals (see Chapter 4), and to develop project planning and management according to the logical framework approach method (LFA, NORAD, 1999). Additionally, a scheme known as "future workshop" has been used widely (Skoglind-Öhman and Shahnavaz, 2004) as have the ILO (1996) ergonomics checkpoints.

7.2.1 Workshops Designed for Top Management

To introduce ergonomics in a company or organization, the support of top management is crucial. It is important to inform top management that ergonomics can contribute significantly to the creation of a healthy and productive company. Spending money on ergonomics improvements should be regarded not as a cost, but as a cost-effective investment. Ergonomics, combined with health and safety, should be a part of management's goal and policy. All top managers should participate when developing an ergonomics vision and goal. It is important to have a common goal to which top management has contributed and which it accepts, and is willing to work toward. Lack of employee commitment is the major constraint upon the improvement of a company (Mullins, 1996). To get employee commitment, participation is necessary. Therefore, it is important that top management

receives training in participation in order to understand its benefits. Workshops training top management in participation and developing an ergonomics vision and goal were regarded as essential "know-how," and as a starting point for introducing ergonomics in a company. We suggest a one day workshop on creating an ergonomics vision and goal for top management.

7.2.1.1 Workshop on "Vision and Goals" for Top Management

In this one day workshop, top management should be introduced to basic ergonomics and its benefits to the company and the employees. Additionally, the benefit of participation and involvement of the workers should be discussed. Further, in order to show the benefit of participation an exercise is carried out. In this exercise, top management try to develop a common ergonomics vision and goal for the company, and discuss various projects and activities to be conducted in order to achieve the proposed vision and goal (see Chapter 4).

7.2.1.2 Workshops Designed for Middle Managers

To create general ergonomics awareness among top and middle managers, our experience shows that starting with a two day workshop on basic ergonomics is appropriate. The first day one needs to concentrate on the definition and scope of ergonomics, continuing with a brief description of the human at work. The human-at-work system is influenced by the technology used to do the work, and the environment and organization in which the work is done. This is known as the "human-work system." The goal of a good human-work system is to adjust the technology, environment, and organization to suit the human and not vice versa. The first day continues with a brief description of human capacity (physical and mental), limitations and preferences, then shows how the technology, environment, and organization should be designed and adjusted to the human in order to create a healthy, happy, and productive worker. The second day focuses on how to create participation, engagement, and optimum utilization of the human resources of a company, and the concept of future workshop is introduced. Workers at floor level have knowledge and experiences which could benefit the company if they are given the opportunity to participate in solving problems at the workstation. Participation promotes engagement and commitment to the company. Our experience shows that future workshop is an easy and appropriate method to create participation and utilization of human resources which top and middle managers can use later on in their divisions. Future workshop usually takes two days to complete.

7.2.2 Future Workshop

Future workshop is a sociopedagogic method for identification of common problems in an organization or company. Through participation, a common vision and an action plan are developed by the group concerned. Future workshop helps to develop a complete "problem catalogue" related to the selected theme of the workshop. This theme can be selected freely, such as problems related to the working environment, productivity, or quality. The method was first introduced by the "future" scientist Robert Jungk from Germany in 1984 (Jungk and Müller, 1987). Later it spread successfully to the Scandinavian countries and is now widely used as a valid and successful participatory intervention method worldwide (Skoglind-Öhman and Shahnavaz, 2004; Mohammed-Aminu, 2006). Experience has shown that after running a future

workshop and developing a problem catalog, it is convenient to use the LFA for each problem identified. In this way, the participants can easily see if they have the required resources to carry out the selected project strategy, or if they need to select an alternative project strategy. For detailed analysis how to carry out a future workshop refer to Chapter 4.

7.2.2.1 "Logical Framework Approach" Workshop

The LFA method was developed by Leon J. Rosenberg in 1969 and is now an internationally accepted and widely used tool for improving project quality (NORAD, 1999). LFA is very useful for those responsible for planning, implementing, and managing of projects/programs and is used in all phases of a project/program. LFA ensures that fundamental questions are asked and weaknesses are analyzed. Further, it improves planning by highlighting links between the project elements and external factors. The LFA approach, starting with a current unwanted situation/condition (a problem) using objective-orientated project planning and management toward a future wanted situation/condition, is appropriate for ergonomics interventions and thus we have introduced and used the LFA approach in many countries.

The end result of an LFA analysis is a one page summary, a project matrix (PM). The PM facilitates common understanding and better communication between decision makers, managers, and others involved, and ensures continuity of the approach when the original project staff are replaced, because it provides information on:

- Why the project is carried out, e.g., who/what will benefit? (the target group).
- What the project is expected to achieve (purpose, and in the long run the goal).
- How the project is going to achieve its output/results (activities).
- Which external factors are crucial for the success of the project, e.g., risks and frame condition (assumptions).
- How to assess the success (indicators).

Our experience has shown that four days is a minimum for running an LFA workshop because participants need time to "digest" and practice to fully understand the principles, and to be able to start using LFA for their own project ideas. An appropriate approach to learn LFA is to use group work during the workshop where each group develops a group PM, and individuals work afterward (each participant prepares and hands in an individual PM using a personal project idea). In this way, the participants learn the basic concepts of LFA during the workshop, supported by the teacher and in participation with the group, and then repeat the method when analyzing their own project ideas. It is important to go step-by-step and give all groups enough time to prepare and present each step, and to expose the class to several different approaches of applying the LFA method.

Day 1: The first day starts with forming groups of five to six and introducing the basic components of LFA. We have seen that many only have a vague idea about the difference between purpose and goal. Thus, we use the LFA model which shows how the purpose is directly related to the project and something the project manager hopes to achieve; while the goal is related to the "higher" area/sector and something the purpose will contribute to in the long run. A simplified model is shown in Figure 7.1.

We present problem formulation according to LFA, viz., a problem is an existing negative state (not a possible, imagined or future problem, and not an absence of a solution),

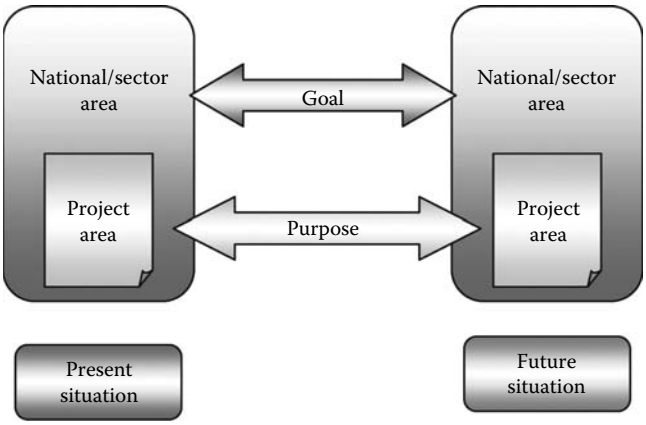

FIGURE 7.1
A simplified model showing that a project is part of a larger concept with the purpose directly related to the project, while the goal is related to the larger concept.

followed by participation analysis, target group analysis (whose interests and views are to be given priority when analyzing a problem) and problem analysis. We show how to develop and present a "problem tree" including major causes and major effects and how to reformulate all elements of the problem tree into positive desirable conditions and develop an "objectives tree." We also discuss how to identify different projects from the objectives tree, alternative analysis (briefly), and selection of a project strategy. Each group discusses and agrees on a "problem," they would like to use for an LFA analysis and present it to the class, in order to make sure all groups have formulated the problem appropriately and according to LFA.

Afternoon, Day 1: Based on the problem agreed upon, each group works together to develop a problem tree. Our experiences show that it is easier and faster to identify the effects of a problem than the causes. Thus it is important to give the groups enough time to discuss the causes and prepare the problem tree. If the instructor sits with each group for a short while, listens, discusses, and offers support during the group work, this has shown to be very useful. Our experience has revealed that adults often prefer discussing face to face when learning a new, somewhat complex tool, rather than raising questions in front of the class. Most groups need at least half a day to develop a problem tree.

Day 2: In the morning, the groups present their problem trees to the class. Again, it is important to have enough time to go through each one carefully and make sure that causes and effects are thoroughly covered, but not too detailed. It is interesting to note that, even with unfamiliar problems, participants can often contribute significantly when assessing the problem trees of other groups. After the presentation of the problem trees the group work continues, reformulating the problem trees into "objective trees." They further need to identify possible project alternatives, to briefly assess the feasibility of the different options, the probability of achieving the objectives and finally, to agree upon one project strategy.

Afternoon, Day 2: We briefly introduce the PM and formulation of the goal, purpose, input, activities, output, and assumptions as well as indicators, according to LFA. We further show how to draw information for the PM from the objective tree (see Figure 7.2). Thereafter, the

Goal	Indicator	Assumptions
Purpose	Indicator	Assumptions
Outputs	Indicator	Assumptions
Activities	Inputs	Assumptions

FIGURE 7.2
The project matrix provides a one page summary of a project.

groups continue developing their objective trees and discuss information needed for the PM. Support is given to the groups during all group work discussions.

Day 3: In the morning, each group presents its objective tree and the selected project strategy the group has agreed upon. Again, it is important that the groups receive feedback and that a thorough assessment of all objective trees is carried out with participation from the class. This usually takes half a day. After the presentation, the groups start to develop their PM.

Afternoon, Day 3: Each group continues working on their PM, supported by the instructors. While participants often find the "activities" easy to formulate, the formulation of outputs, purpose, and goal according to LFA, often are tricky. The indicators define not only how but also when to measure the achievements, which can only be done if goal, purpose, and outputs have been formulated correctly. After 2–3 h group work, we present how they should evaluate the contents of a PM by checking, from bottom-up, according to Figure 7.3.

Day 4: Each group presents step-by-step how they have developed their PM, and discuss the consistency of it. This usually takes at least 1 h per group. The class is encouraged to raise questions and discuss each PM.

After the presentations, we summarize and emphasize that LFA is one of several tools to be used during project preparation, implementation, and evaluation and that it does not replace other activities such as target-group analysis, cost–benefit analysis, time planning, or impact analysis. Further, they should not overemphasize objectives and external factors to avoid rigidity, and they must carry out a regular project review where the key elements are reevaluated and adjusted. Also, they must be aware that full benefit of utilizing LFA can be achieved only through systematic training of all parties involved and methodological follow-up. In addition, we show how several small ergonomics projects can be part of a larger ergonomics program/process (Figure 7.4).

It is useful for participants to evaluate the consistency and logical connection in different PMs and thus the groups assess and select the best PM, and the winning group receives a small reward. Finally, each participant is encouraged to hand in a problem tree, objective tree, and PM for evaluation and assessment. By developing an individual PM immediately after the workshop, participants receive feedback and the training necessary to be able

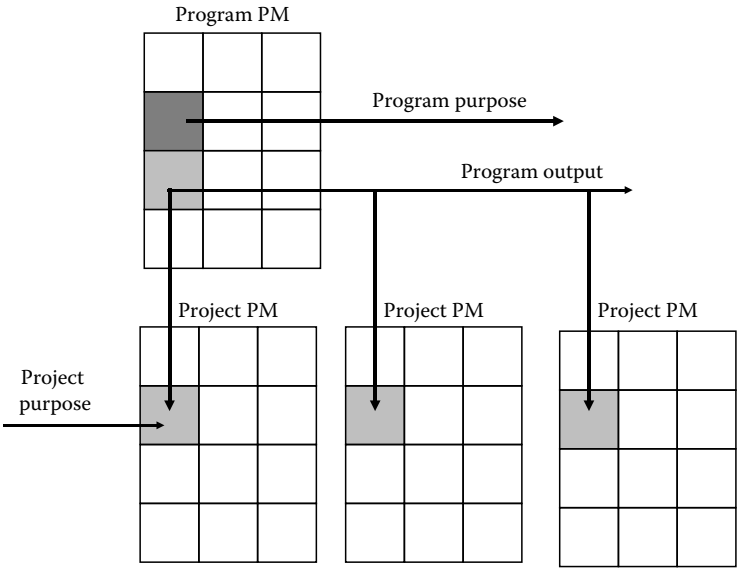

FIGURE 7.3
PM of a large program with output equivalent to purposes received from three small projects.

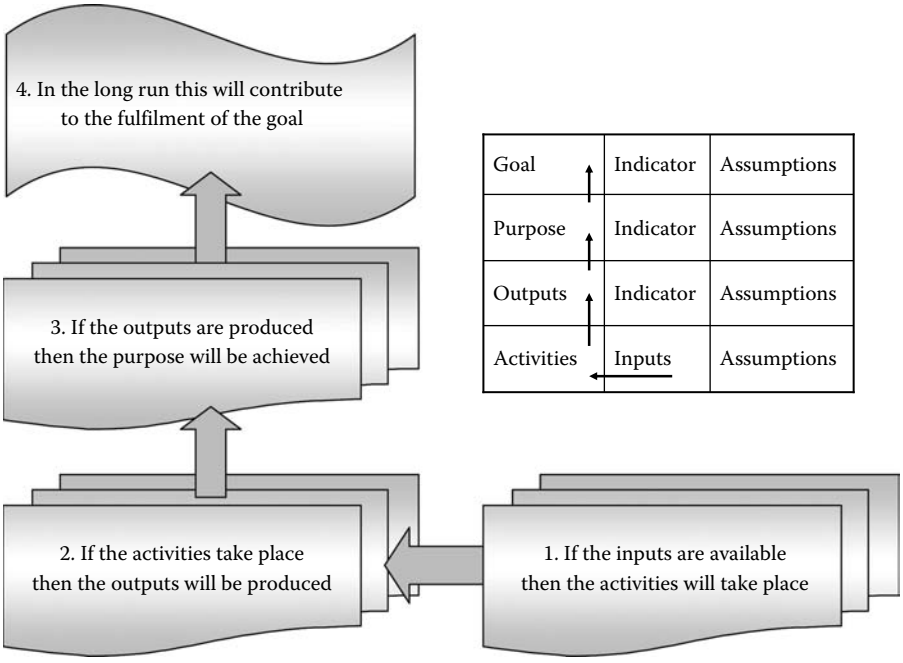

FIGURE 7.4
Checking the consistency of a PM starting from bottom and up.

to use the LFA method. In our experience, when teaching the LFA method to managers in IDCs, participants have often expressed that this was the first time they really understood the meaning of the project elements, the connection between the different project elements, and how to follow a project. For more detailed information please refer to *The Logical Framework Approach* handbook for objectives-oriented planning NORAD (1999).

7.2.3 Workshops Designed for Line Managers and Shop-Floor Workers

Line managers are engaged in everyday activities and are well aware of the production process and related problems, while shop-floor workers are those who carry out the work and really feel the problems related to the production line. Usually, the workers also have practical and feasible solutions as to how to solve productivity, health, and safety problems if they get the opportunity to express themselves. Unfortunately, in many workplaces in IDCs, hierarchal management organizations provide no room for workers to participate in solving problems. Our experience, from workshops conducted in IDCs, has shown that if workers are given the opportunity to participate in decision making they can identify most of the workplace problems and provide feasible and practical solutions. In order to create ergonomics awareness among line managers and shop-floor workers, we recommend using a three day workshop on *Ergonomics Checkpoints*.

7.2.4 The *Ergonomic Checkpoints* Workshop

The *Ergonomic Checkpoints* booklet is the result of collaboration between the International Labour Office (ILO) and the International Ergonomics Association (IEA), and is intended for those wishing to apply practical improvements to existing working problems. It helps users to check workplaces in an organized manner and presents various kinds of simple, inexpensive, and applicable solutions (ILO, 1996). The booklet has been translated into many languages and is one of the most used materials in IDCs (Scott and Shahnavaz, 1997).

Improvement of a workplace needs to be conducted with participation of the employees and support of the management. Analyzing a workplace and the planning and implementation of practical solutions are most successful if they are conducted in a cooperative manner by a team of people who are affected by the problem. In IDCs use of available local materials and expertise has many benefits. However, continuing action programs are needed to create improvements, and multifaceted actions should ensure that improvements are sustained over time.

The *Ergonomic Checkpoint* booklet is comprised of 128 checkpoints where:

- Each checkpoint indicates an action
- Options for that action are then described
- Checkpoints are put together in the form of a list which can be used as a checklist

All checkpoints are explained with simple figures and illustrations, which make it easily usable. These *Ergonomic Checkpoints* cover all the main ergonomics issues at the workplace, and the number of checkpoints in each area is given in brackets below.

1. Materials storage and handling (21)
2. Hand tools (15)
3. Production machine safety (20)

4. Improving workstation design (15)
5. Lighting (10)
6. Premises (6)
7. Control of hazardous substances and agents (7)
8. Welfare facilities (5)
9. Personal protective devices (8)
10. Work organization (21)

Having conducted many *Ergonomic Checkpoints* workshops around the world, we have found the following method useful for a three day workshop:

Day 1: The participants receive a half-day session of tuition in basic ergonomics. The rest of the day is spent on introducing the *Ergonomic Checkpoints* book and explaining how to use it.

Day 2: The participants are divided into groups of six (maximum seven) members and specific checkpoints are allocated to the groups. Each group works on its assigned checkpoints, reading, discussing, and trying to find examples from their own work experience related to their checkpoints. They spend half a day on this activity.

In the afternoon of day two, a factory is visited. Each group continues to apply its allocated checkpoints, going through the workplace together concentrating on the assigned checkpoints and assessing the workplace. Each has to find out whether an action with regard to the checkpoint in question is needed or not. If yes, what priority would the group suggest? They also add remarks in respect of the checkpoints they suggest should be prioritized. They discuss each checkpoint within the group and with the operator in charge. They also identify good working conditions and good practices where these are observed.

Day 3: The participants go through the information they have collected at the industry visited and prepare a presentation for the whole group. The presentation should contain problems they have observed and the solutions they suggest for improvements. In the afternoon, the groups present their findings and recommendations to the entire group. We always invite a representative of the industry to attend the presentations. After the presentations a general discussion is conducted. It is useful for participants to evaluate different groups' presentations and select the best one. The winning group receives a small reward.

7.3 Discussion and Conclusion

Many workshops in IDCs have been carried out through the auspices of the Centre for Ergonomics of Developing Countries (CEDC). In our experience, workshops conducted with employees in a specific factory were most effective. Apart from achieving the aim of the workshops, many ergonomics applications were suggested for improving working conditions and productivity. In workshops with participants from different areas however, few examples of applications were proposed and conducted by the participants. The reason is that in the first case, these workshops have the full support of management of

the company, while in the latter case, although the individual participants had received permission to participate in the course by the managers, as individuals it was difficult for them to intervene. Thus, if the aim of the workshop is to improve actual working conditions and productivity, it is crucial to receive full support of the management, and also to conduct the workshop *in situ* and for all the participants to receive action training.

Our experience shows that for successful ergonomics interventions it is advantageous to start with top management, in order to develop a common ergonomics vision and goal. From this base it is appropriate to move to top and middle managers together and run a future workshop in order to develop a problem catalogue, prioritize the problems, select them one by one, and finally use them in the LFA analysis. This gives the participants a better view of the extent of the problem, the resources available, plus the resources and activities needed to solve the problem. Lastly, it is crucial to engage the line managers and shop-floor workers in ergonomics. For this, utilization of the *Ergonomic Checkpoints* is a useful and easy tool. In that way, top-down and bottom-up approaches are combined to achieve an optimal result.

Many projects in IDCs do not achieve their purpose and goal due to unrealistic evaluations and assumptions. In some cases the project cost is much higher and the duration of the project much longer than anticipated due to bad planning. The project elements are often very abstract, even for experienced people, and the link between project elements are not clear. A more thorough understanding of LFA was achieved in workshops run over a longer period of time, such as a month, with a half to full day workshop per week. The maximum benefit of utilizing LFA can be achieved only through systematic training of all parties involved and methodical follow-up.

We have used the *Ergonomic Checkpoints* book even for graduate students in ergonomics. After using the tool in practice at several industries, the *Ergonomic Checkpoints* gave the students a holistic picture of workplaces and taught them to work in teams. The tool also taught them the importance of operator participation when assessing and proposing a solution for improvement. We have carried out workshops using *Ergonomic Checkpoints* for participants in IDCs which had not hitherto even heard the word ergonomics. After using the book, they showed a significant level of knowledge probably because the tool draws out hidden knowledge and common sense from people, but also due to the participatory approach and the group dynamic it facilitates. Another advantage is that you do not need previous knowledge to be able to understand the content of the *Ergonomic Checkpoints* booklet, because it is easy to understand and implement.

By inviting management representatives to the presentations of workshop participants, shop-floor problems are illustrated, sometimes for the first time for the manager. Some managers even pointed out that now they understood the importance of solving some of the problems presented. The very simple solutions which often are the result of the workshop could be implemented with no- or low-cost, using mostly local available resources of the company.

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8

Participatory Ergonomics: A Case Study Implementing an Ergonomics Program in a Specific Brazilian Company

Marcelo M. Soares

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8.1 Introduction

The objective of this study was to implement an ergonomics program (PROERGO) in an alcoholic drinks company in the northeast region of Brazil. An ergonomics program is understood, in this context, as an action plan defined for the company and involves

solving ergonomically related problems, training facilitators in this area of knowledge, and defining strategic guidelines which may contribute to identifying, analyzing, preventing, and controlling risks in the company (Hendrick and Kleiner, 2001; Vidal, 2002; Silveira, 2004). Wilson and Haines (2006) have defined participatory ergonomics as "the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals." Wilson et al. (2005) state that the benefits from the use of participatory approaches may include improved industrial relationships, opportunities for personal development among those involved and a spread of interest and expertise in ergonomics. According to Spielholz and Carcamo (2006), the benefits of a successful ergonomics program may include not only reduced injuries and worker compensation costs, but also reduced absenteeism, as well as increased morale, productivity, and product quality.

The company under study is situated in the metropolitan region of Recife, in the state of Pernambuco, Brazil. It comprises an administrative unit and production unit, and is classified as a drinks bottling industry. There are three work-shifts, the last of which is for maintaining the production line and loading trucks for clients. All company staff work fixed hours, without stopping. Most of the activities in the plant require manual labor by employees whose level of education is to have completed secondary school. Initially, at the request of the company, problems were identified in 31 work-sites in the production sector. Thereafter, three work-sites were selected in order to subject them to ergonomics analysis. These were the platform (responsible for the unloading of crates of drinks received in the delivery truck), the loading and unloading zone, and the inspection department.

The goals of conducting the study were:

- *Application* of the knowledge and competences of the specialist in ergonomics in assessing the organization of production, working conditions, and conceiving solutions which combine human factors and technical aspects.
- *Training* of the members of the company's ergonomics committee (ERGOCOM) and other facilitators by means of generic training courses and customized courses to meet the company's specific needs.
- *Discussion* of the implementation of the program with ERGOCOM members based on the definition of strategic guidelines in order to identify, analyze, prevent, and control ergonomically related risks in the company.
- *Implementation* of ergonomic actions with a view to analyzing and finding solutions for these problems in the following areas: physical (e.g., postural, dimensional, instrumental, information and perceptual, and activity-related problems), cognitive (mental workload, decision-taking, stress, and training), and organizational (organization of work, monotony, and group work) identified in the first stage of the study—ergonomics appreciation.
- *Affording* continuous assistance in the course of implementing solutions with a view to ensuring success with the ergonomic actions implemented and to generate indicators which can measure the success of these actions.

According to Silveira (2004), a program is a project written in minute detail which leads to a good understanding of the fine requirements of a plan. Ergonomics programs are not isolated plans. They only make sense when they form part of company policy for a healthy and safe work environment; that is, they are part of the company's strategic plan. An ergonomics program is also the best solution for organizing management actions because it

captures the complex reality of the work environment in small pieces, thus making it comprehensible, subject to planning and manageable. These produce technical solutions, the implementation of which depends on how people who make up the organization face up to the problem in an organized, attentive, and practical way.

The main advantages of implementing an ergonomics program in a company, according to Silveira (2004) are (a) more consistent actions, thus increasing the chances of partnerships with, and involvement of, the beneficiaries, and generating an impact; (b) people mobilized to participate in actions fostered by the company, thus nurturing internal partnerships; (c) actions leading to improvements in working conditions with better results and fewer costs, thus generating confidence in the organization and among its stakeholders, engendering a feeling of legitimacy and credibility; (d) progressive fostering of collective reflection on the experience, thus generating the production of knowledge relevant to other programs within the company; (e) promotion of space for negotiation and expression of the agents, because this is anchored to targets, objectives and assessment criteria, thus generating negotiation of interests.

8.2 Organizational Structure of the Ergonomics Committee

In order to strengthen the acts of mobilization generated by internal partnerships, the initial action was the formation of an ergonomics committee, it being understood that the workers were the main personnel responsible for the changes. Thus, even before the official start of the program, meetings were held with management to define this committee, which was organized in the format of action groups. It is worth pointing out that the composition of the committee brought together various sectors and work teams, ranging from the strategic level to the operational one. The idea of forming an ergonomic committee by means of action groups is the specific activity of each member within a duly structured plan. Table 8.1 presents the structure of the ERGOCOM, with the concept and objective of each group. Figure 8.1 presents a diagram for the modeling (operational structure) of the ergonomics program in the company. The participation of ERGOCOM in the ergonomics intervention process was necessary, right from the recognition of the problem through the validation of the results.

TABLE 8.1

ERGOCOM Action Groups

Groups	Action
AG1	Interest group (IG) and ergonomics team
AG2	Group being trained in ergonomics, concept, methods, and techniques, with the responsibility for ergonomic action in the company
AG3	Focus group—target operators target of the research
AG4	Ongoing monitoring group—technical authorities
AG5	Support group—decision-making authority in the organization for changes

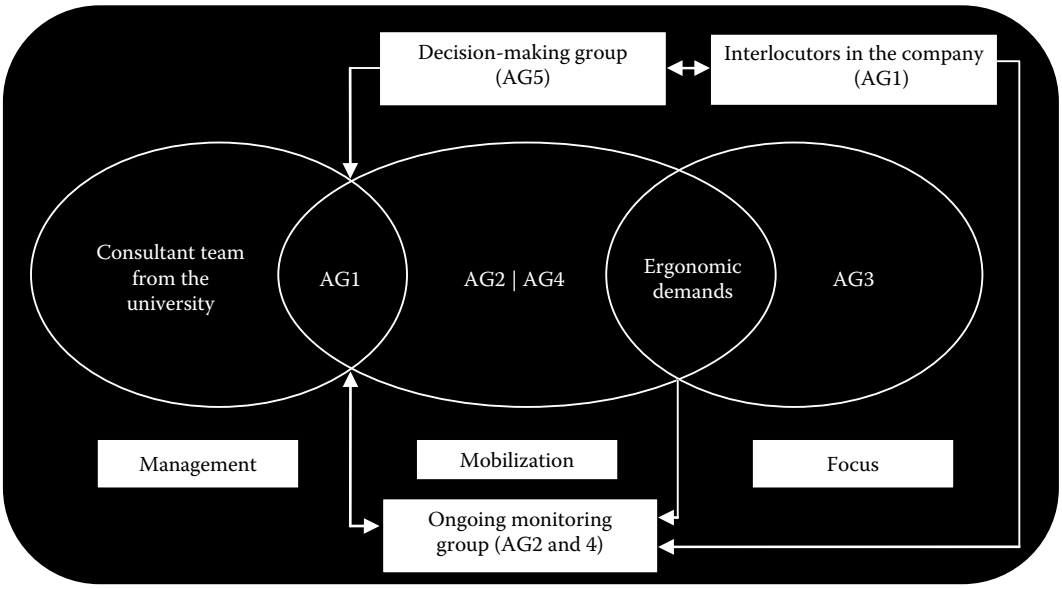


FIGURE 8.1
Operational structure of an ergonomics program in the company. (Based on Silveira, D.M., *Programa de ergonomia nas organizações: reflexões e estratégias para implementação*, Capes/Faperj, Rio de Janeiro, 2004.)

In order to create the ergonomics committee in the company, the following procedures were followed: (a) identify and select workers, preferably volunteers, from various sectors so as to represent most of the company's employees; (b) provide theoretical and practical training on the basics of ergonomics in order to establish an understanding among the members and foster the integration of the sectors; (c) establish a timetable for systematic meetings for negotiation, discussion, and presentation of the recommendations put forward; (d) define action strategies for carrying out the recommendations; and finally (e) generate a procedure for communicating the actions of the program to the rest of the staff. However, it was observed that, because of the trade union organization and the very organizational structure of company, the formation of the committee and the conduct of the activities could occur in different ways. The method used in implementing ergonomic actions was based on an ergonomics analysis of the human-task-machine system (HTMS) which involved surveys and analyses of issues from the physical environment, the worksite, and the organizational factors (layout of the space, rhythm of work, work routine, breaks, and organization of production) which have an influence on the workers' behavior and on the quality and safety of their workstation.

8.3 The First Actions of the Ergonomics Committee

Having started in 2003, the initial study of the company's work-sites evolved into an ergonomics program in 2005 (Figure 8.2). During the initial phase of the program, strategic steps were structured, which permitted them to be carried out in a consistent and

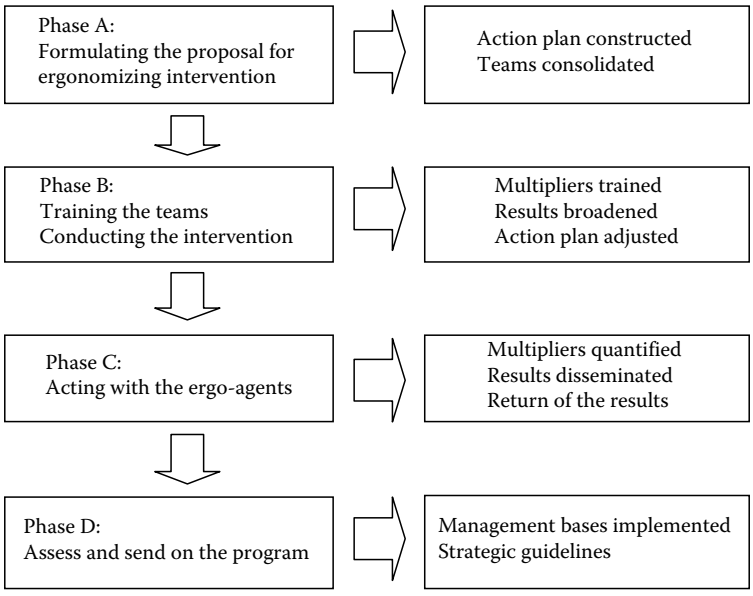


FIGURE 8.2
The four phases which comprise the ergonomics program in the company. (Based on Silveira, D.M., *Programa de ergonomia nas organizações: reflexões e estratégias para implementação*, Capes/Faperj, Rio de Janeiro, 2004.)

organized way. The first step was to form the ergonomics committee, created, in the first instance, to assist in the internal coordination and mobilization of the staff, with regard to ergonomics intervention. The second objective was to ensure that this committee, once trained, would proceed to conduct the study under the supervision of a consultant. The ergonomics committee (Table 8.2) was formed even before the official start of the program. Some meetings were held with top management, in which the physical and organizational structure of the committee was defined. During this step, one of the members of the committee put forward a proposal for visual identity which quickly became the icon of the

TABLE 8.2

Action Groups of the Ergonomics Group in the Company

Groups	Action	Agents
AG1	IG and external consultancy	ErgoLab Team; HR Coordination Unit; Occupational Health (OH) Doctor
AG2	Group being trained in ergonomics, concept. Methods and techniques, with the responsibility for ergonomics action in the company	OH Doctor, Specialist in Safety; Human Resources Team; Coordinators of the Production areas; Logistics; Standardization; Quality; Engineering and Maintenance
AG3	Focus group—target operators of the research	All the shop-floor workers and office staff
AG4	Ongoing monitoring group—technical authorities	Staff in charge of the production areas and logistics
AG5	Support group—power of decision in the organization for changes	NE Plant Manager

ergonomics program. Today, this image is used in the ergonomics advertising campaigns of the company. The members of the action group (as pointed out in Table 8.1) took part in assessing the work-site demands, but they could only access the documents made available in a virtual folder of the program which was open to the public, and which contained information that had already been validated by the groups, schedules for undertaking recommendations and the copies of the training events held.

The launching of the program was planned as the committee's first action: an event which lasted three days with various activities during this period:

1. *Opening*—A general lecture on how the ergonomics program in the company would work was held for an audience of more than 150 company staff in the warehouse of the plant.
2. *Systematic activities*—Programmed sessions of talks given by members of the ErgoLab, with the theme "Day-to-Day Ergonomics." The talk was given to five groups, which included a 100% of stakeholders, including third-party contract staff. During the talks they were requested to complete a questionnaire to identify positive and negative points in each sector. The objective was to capture, spontaneously, all elements of dissatisfaction felt by the stakeholders.
3. *Activity for which points awarded 1*—Showing of the film "Modern Times," with Charles Chaplin, in the company refectory, in order to awaken the critical spirit of ergonomics among the staff.
4. *Activity for which points awarded 2*—Competition on phrases which would express the concept of ergonomics for the company, launched on the opening day, with a deadline for entries on the final day of the event.
5. *Closing ceremony*—Formal ceremony to present awards for the best phrases in the competition and official introduction of the ergonomics committee to all employees.

Thereafter, as the second phase of the Launch of the Program, training events run by the ergonomics committee took place. The objective was to provide more intensive training in ergonomics to the members of the AG2 and AG4 groups. All the classes took place during working hours, over two consecutive weeks in the month of March and another two weeks in May 2005. In parallel with the training sessions the ErgoLab team, in partnership with the ergonomics committee, began the activities of "Exploring the Demand." Since the first ergonomics analysis of the company took place in 2003, a reanalysis of the health and safety conditions of the stakeholders was needed, with a view to comparing the past situation to the current one. In order to conduct this reanalysis of the problems stated in the 2003 report on the ergonomic appraisal, a checklist based on the problem data was drawn up and used to identify which were to be the three current priority sites for intervention. Using the perspective of lessons learned, initially the ergonomics committee followed the consultant ergonomics team in the analysis of the first work-site which was the platform. Next, after the first analysis had been concluded, and action proposals and strategies drawn up, the members of the ergonomics committee conducted the second and third analyses, and were supervised by the consultant team so they had adequate technical support. To do so, specific (physical and organizational) work groups, with a mixture of representatives from action groups AG1, AG2, and AG4, carried out the analysis with the aim of implementing the demands of the work-sites at the platform, as pointed out below:

- Physical group—directed toward the recommendations of a dimensional order and physical changes of the work-site
- Cognitive/organizational group—directed toward the recommendations on people management and work procedures

However, during the start of the second step of the program (analysis of the work of the glass inspector, the *visorista*—responsible for the quality control of bottles after they had been cleaned), the need was noted to subdivide these two work groups still further into: a work group for the platform and a work group for the *visor*. The former was responsible for implementing the recommendations of a physical, cognitive, and organizational order, these being directed toward the platform site, and the latter were responsible for conducting the analysis and diagnoses of the *visor* site. These groups went on to hold monthly meetings, in accordance with demand, and were led by the official communicator of the program—the company's safety specialist. The results obtained from the ergonomics analysis at the platform are presented below.

8.3.1 Ergonomics Analysis of the Platform Work-Site

In order to undertake the ergonomic analysis, the methodology of the systemic approach of the HTMS was used (Moraes and Mont'Alvão, 2003). This consists of three phases:

1. *Ergonomics appraisal*: A survey of the problems and the identification of the dysfunctions of the plant as an industrial unit, and specifically of the work-sites of the production workers. Within the steps which comprise the ergonomics appraisal there are the problem identification of the HTMS; the systematization of the HTMS; the ergonomics report on the HTMS and further, suggestions for improvement.
2. *Ergonomics diagnoses*: The macroergonomics analysis, behavioral analysis of the task, analysis of the physical ambience of the task, analysis of physiological components, and analysis of the profile and inputs of the operators.
3. *Ergonomics project*: The configuration, profile, and dimensioning of the work-site and recommendations for operational and physical environment of the work-sites (this was not part of the current study).

8.3.2 Ergonomics Appraisal

The objective of the ergonomic appraisal was to analyze the work-sites in the company's production sector based on identifying possible problems existing in each work-site. Next, a hierarchical ordering of those problems identified as being the most serious was undertaken. Their gravity defined the urgency of solving them. Therefore, aspects of a physical, cognitive, social, organizational, and environmental order were taken into consideration, besides other aspects relevant to the demand of the tasks at the various work-sites. The tool used for analyzing priorities was Kepner and Tregoe's value analysis, also known as the gravity, urgency, and tendency (GUT) technique. The steps which comprised the ergonomics appraisal are presented below.

8.3.2.1 Study of the Functioning of the Company

This initial step targeted understanding how the company worked and analyzing the elements involved in the production process. They consisted of the following phases:

Identifying the production unit—This sets out to present the location of the company, its mission, the type of production, the target public, the area it served, institutional relations with unions and professional associations, and the number of staff.

Drawing up the functional organogram—This was conducted using the hierarchical organogram of the various departments of the production unit with the objective of being able to situate the position of the work-sites which required analysis among the other sites in the company.

Evidencing the production process—This was analyzed by means of (1) drawing up organograms of the production lines of drinks, which characterized the system as semiautomated, displaying direct, and indirect human interference in the tasks of handling and moving the loads, quality inspection of the product, monitoring of supplies for machines, and technical maintenance in the areas of electronics, mechanics, and chemistry; (2) reporting on the raw materials used in the production process; (3) reporting on machines, equipment and processes involved in the production of drinks; (4) map-cum-flowchart of the production sector, in which the layout and flow of raw materials and people in the production process is analyzed; (5) analyzing data on the planning, programming, and control of production, including the hours of working, number of staff, planning of production, pauses and changes of shift, production targets, graphical signposting of the production sector (luminous signposting and safety signposting); and finally (6) characterizing the products, rejects, and residues.

Description and characterization of manual workforce and social benefits—Using assistance from the human resources sector, the following matters were identified and analyzed: (1) age and sex of the workers by sector; (2) level of school education; (3) selection criteria for admission to the company; (4) training after admission to the company; (5) identification of the criteria for dismissal; and (6) other aspects, such as the criteria for granting holidays, transport, social benefits, leisure activities, and salary income.

Analysis of data on health and safety—Analyses were made of data obtained from the sector called specialized service in safety and medicine of work. Data were analyzed relating to the admission examination, periodic examination, return to work, change of function, and dismissal. Also analyzed were data referring to eating habits as a health factor in the company. A request was made to see the company's medical service for documentation on registering and controlling the obesity of employees. The data referring to the register of occupational diseases were requested with the objective of being able to determine and locate the possible sources which generate problems related to ergonomics. An analysis was also made of the register of accidents at work, chemical risks, and physical risk (noise, vibration, temperature, and illumination).

Verbal reports—Meetings were held with representatives of the workers from the production line, with the objective of discussing questions relevant to the ergonomics study on the work-sites of the plant's production line. Representatives of the workers in the production, logistics, and administration sectors took part in the meetings. Based on these verbal reports, problems in these three areas were recorded.

8.4 Analysis of Problems in the Human-Task-Machine System

This comprised the selection and classification of different aspects of the problem situation and used systematic observation of all the relevant problem elements. The objective

(a) (b)

FIGURE 8.3
Example of postural (a) and architectural (b) problems while doing work at the work-site of the platform.

was to identify what was wrong, harmful, did not work, was missing or degraded the work situation. The problems were categorized and presented through photographs. Figure 8.3 shows examples of problems found at the platform work-site, in the activity of "manipulation." In this activity, the operator was responsible for organizing and keeping the work area clean, accounting for the number of cases which come onto the platform, separating the rejects, broken cases, and bottles and sending on the cases to the transport conveyor belt. Once the problems were identified, they were ordered into a hierarchy so as to prioritize the work-sites which would be the focus of the ergonomics intervention. The platform work-site was considered one of the most critical in the company's production area, and therefore urgent ergonomics intervention should take place. For contractual reasons, the steps described below were only implemented in the second phase of the ergonomics intervention in 2005.

8.4.1 Analysis of the Company's Documentation

Considering there had been a gap of almost two years since the first analysis of the company's documentation, a reanalysis was needed for the health and safety conditions, with a view to comparing the past situation with the current situation. In order to conduct the reanalysis of the problems identified in 2003, the report of the ergonomics appraisal was taken as a base. The situation was discussed with the ergonomics committee and it was decided to draw up a checklist based on the data in the report in order to check the current situation. It was observed that all problems previously identified continued to exist. Parallel to the analysis of the problems at the work-site, an assessment of the HTMS was undertaken.

8.4.2 Systematization of the Human-Task-Machine System

The HTMS concept is one of the basic concepts of ergonomics, and focuses on the interaction of human beings with their tools, equipment, machines, and work ambiences. Starting with the evolution of the models of the HTMS, new paradigms have been introduced, and cognitive issues and issues of convergence in communication and the primacy of human beings have been emphasized. Therefore, this makes explicit the pertinence of modeling human-task-machine communication, as a way to guarantee the considerations involved in all variables of the system, thus allowing for all the aspects of the interaction to be

considered. The objective of this step was to present the HTMS based on models which characterize the serial position of the system, its hierarchical ordering, expansion, and communication modeling. First of all, the characterization and serial position of the system was conducted with the objective of having a better understanding of the relations of the target system with the elements which characterize it. Therefore, the following were defined:

- Its *goal/mission* (what is the system for?)
- Limiting *requisites/attributes* and associated attributes (what should the system have and/or what should the system be?) which foster achieving the goal of the system
- *Environment* of the system, which is "outside" the target system and which explains boundaries and influences, and imposes limits on the target system
- *Restrictions* (fixed coactions) which are in the environment of the system and place obstacles in the way of implementing the requisites
- *Entries*, which determine the actions of the system, and which will be processed to generate *exits*
- *Unwelcome results*, which explain faults or diversions of the system (accidents, defective products, rejects, and pollution)

Figure 8.4 presents the characterization and serial position of the system, in which the target system (the platform work-site) receives goods from a system which is prior to it (a truck or a pallet) and, for its part, produces goods for a system which is located posterior to it in the production line (the unpacking machine). So, the primary goal of the target system is to feed the production line with empty one litre bottles and plastic crates in conformity. It was identified that the platform work-site assumes an important role in the company, as it controls what enters by way of bottles and crates of drinks, and what goes out by way of rejects. The control performed at this site serves to measure the quantity of breakages in production, since the quality program has the number of empty bottle breakages as production indicators.

Thereafter, a model of the hierarchical order of the system was mounted. The objective of this model was to position the target system in accordance with its inclusion within the hierarchy. There are superior hierarchical levels which are the suprasystem and the supra-suprasystem, up to the ecosystem, and inferior hierarchical levels consisting of subsystems, sub-subsystems, and sub-sub-subsystems (Figure 8.5). The next step in systematizing the HTMS was the design of the functional action-decision flowchart (Figure 8.6). This flowchart shows the sequences of the functions/operations (in series, simultaneous, alternative) and the decisions implied.

8.5 Ergonomics Diagnostics

This step of the project, diagnostics, aims at the implementation, supervision, and monitoring of the policy of implementing the ergonomics program (PROERGO) in the company. This enables the prioritized problems to be examined in depth and predictions to be tested, and this phase of the ergonomics method takes into account the technological ambience,

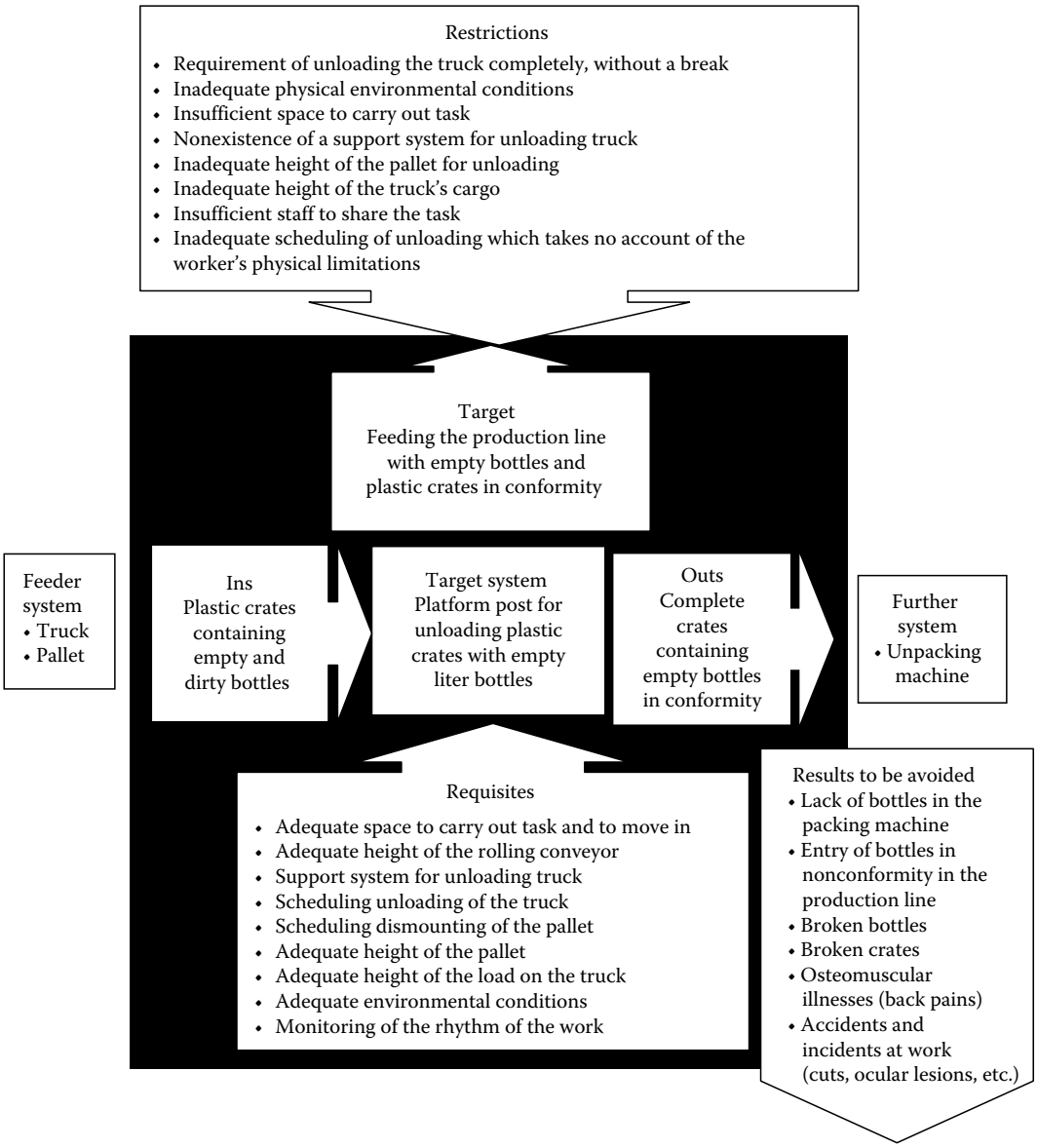


FIGURE 8.4
Model of the characterization and serial position of the system.

the physical environment, and the organizational environment of the task. It involves the systematic observation of the activities of the task and the recording of behavioral patterns in the work situation. Video recordings, structured interviews and verbalizations were carried out, and questionnaires and scales of evaluation applied. Also recorded are frequencies, sequences and/or duration of postures assumed, putting actions into practice, communications, and/or poor locations. This phase also involves a review of the literature and ergonomics recommendations in terms of environment, arrangement, and

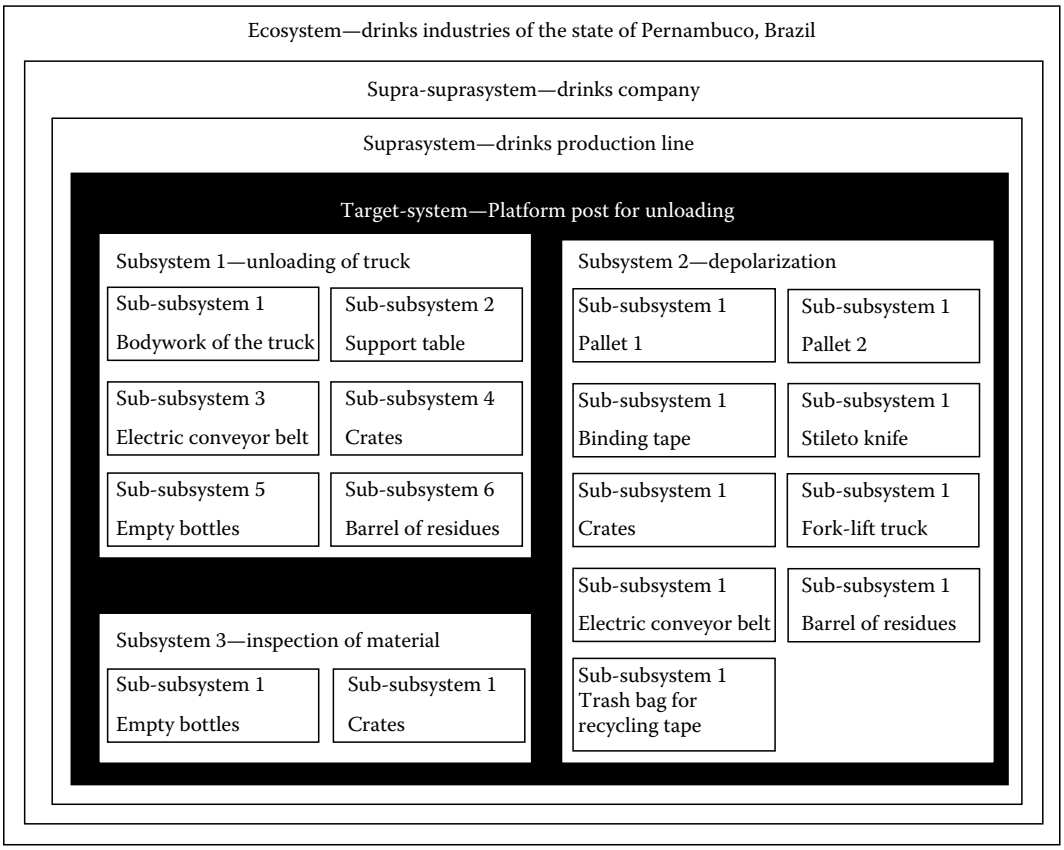


FIGURE 8.5
Hierarchical ordering of the system.

conformation of work-sites, their subsystems and components, programming the task and breaks. The level, amplitude, and depth of the survey of data and of the analyses depend on the priorities defined, on the available deadlines, and on the budgetary resources. This phase is brought to an end with the ergonomics diagnoses which comprises the confirmation or rejection of predictions and/or hypotheses. The first step of the ergonomics diagnoses was to conduct interviews with the workers to obtain information on their physical and psychological conditions and their opinions about the equipment and the work environment. The next item presents, in summary form, the results obtained.

8.5.1 Interview with the Workers

The interviews, applied through questionnaires, were conducted with the objective of obtaining: (a) data on possible physical and psychological constraints that the workers perhaps may suffer from in their work place; (b) subjective opinions about the equipment and the work environment; and (c) suggestions for the improvement of the equipment and of the work environment. All workers ($n = 101$) from the production sector were interviewed at various times of day. Most of the respondents related to the industrial sector of

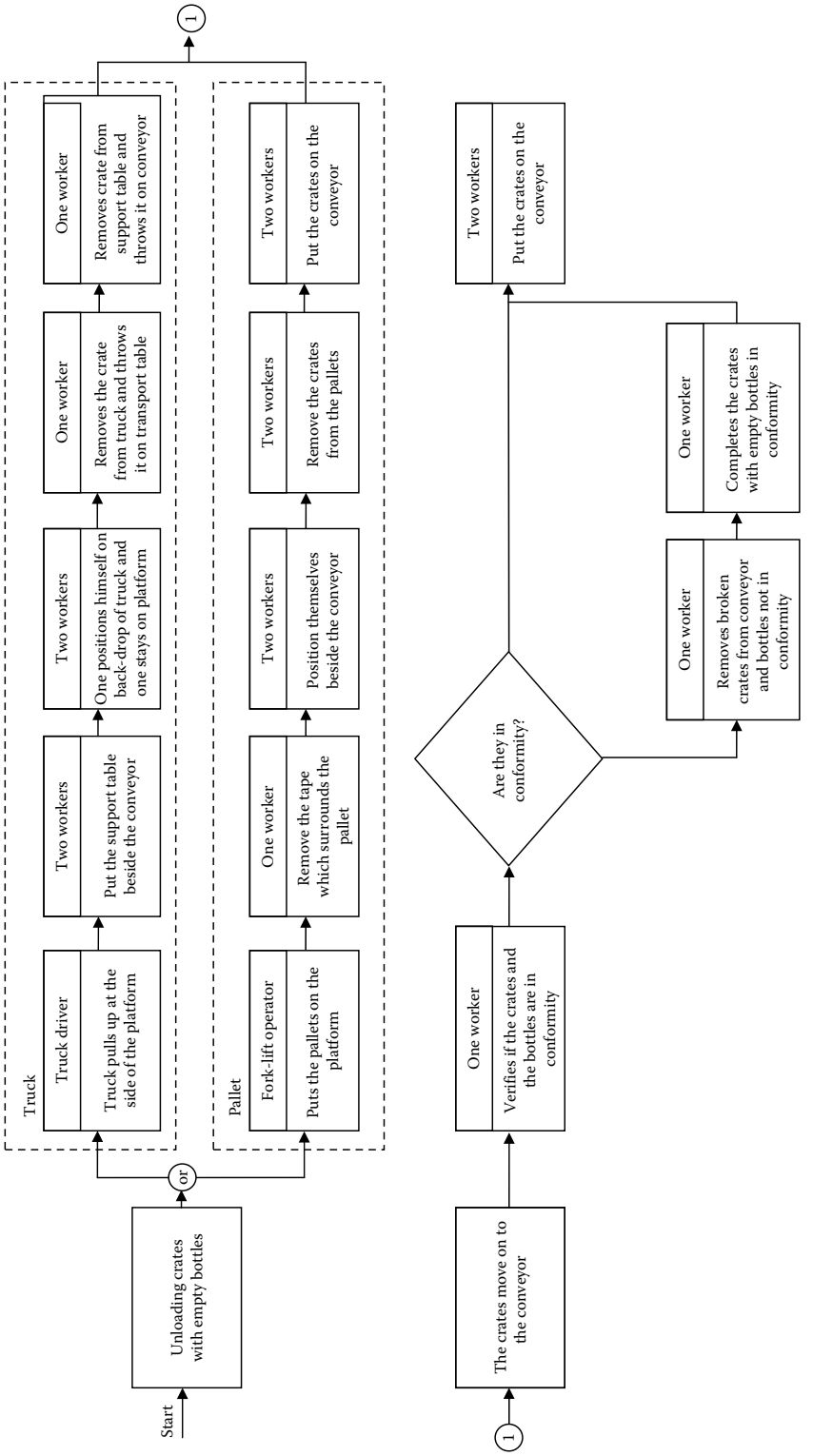


FIGURE 8.6
Action-decision functional flow chart.

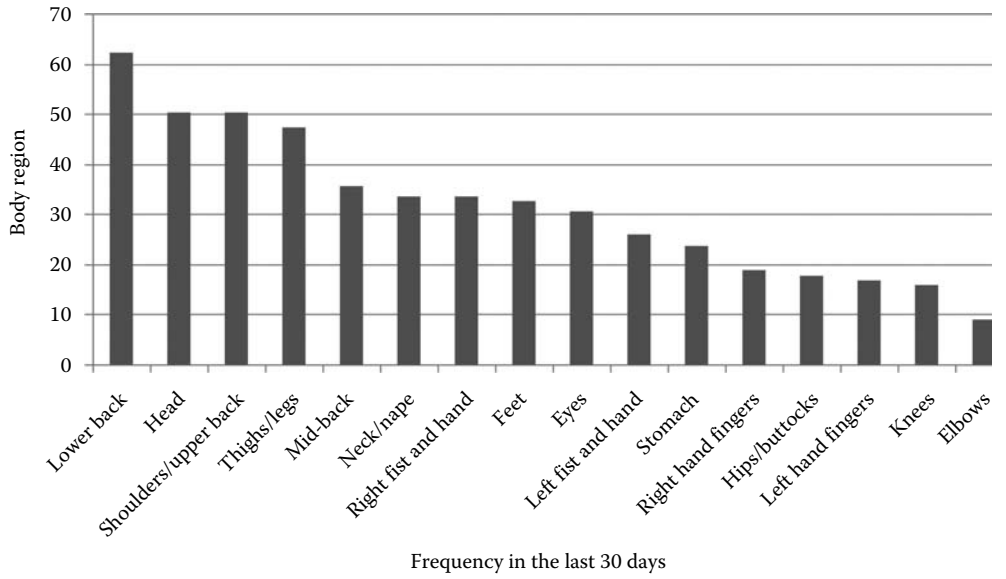


FIGURE 8.7
Discomforts felt in regions of the body over the last 30 days by the workers of the industrial sector.

the plant (86%) consisted of male staff, while only 14% of the production staff were female. The average age of these staff was 30 years. The question asked was if the workers had suffered from any illness in the last 30 days, and 27.6% of the respondents said they had flu, followed by muscular problems (18.4%). Figure 8.7 shows the ailments suffered by the workers in the last 30 days. It was observed that the region of the lower back was the most mentioned by the respondents (62.4%), followed by the head and shoulders/upper back, both with 50.5%, as well as thighs and legs mentioned by 47.5%. Thereafter, the workers were asked to state the regions of their body where they had felt the most pain or discomfort in the last 12 months. The five regions most mentioned were: lower back, (60.4%); head (53.5%); thighs and legs and shoulders/upper back, both with values of 43.3%. They were also asked to order hierarchically the five regions of the body in which, lately, they most felt discomfort during working hours. The result shows the regions considered of greatest discomfort: lower back (15.76%), head (14.61%), and wrists and hands (12.24%). It is important to note that overall, the pain which most bothered the workers was in the lower part of the back, in the head, shoulders, thighs, and legs. Discomfort and pain in such segments are typical when having to maintain prolonged standing postures while moving loads.

Next, the opinion of the workers was sought with regard to the conditions of the work equipment (chair, rolling belt conveyor, and pallets) and the work environment. The interviewees responded negatively to several features of the chair used, with the assessment of "bad" used extensively to assess the five variables in question (height, ease of adjustment, width, and softness of the seat and softness of the chair-back). Of these six, ease of adjustment of the chair was the main problem, identified by 68.2% of the interviewees. The assessment regarding the rolling conveyors was, in general, positive. However, both the spaces between the conveyors, and the space available for movement near the conveyors were assessed as bad by, respectively, 43.8% and 42.9% of the interviewees. As to the pallets, there was a general positive assessment, and both the width and the length of the pallets were judged as good by 53.6% of the interviewees.

Two questions referring to the diagnostic of the work environment were presented. The first requested the workers' opinion regarding eight characteristics of the work environment (lighting, noise, temperature, vibration, ventilation, smell, circulation space, and colors in the environment). The second was based on a hierarchical ordering of the five worst discomforts identified by the workers in the work environment. Temperature and ventilation were considered as the two main problems, assessed as bad by 54.5% and 48.5%, respectively. The last part of the interview dealt with aspects referring to the organization of the work, in order to identify the interviewees' relationship with the various sectors and staff of the company. Generally speaking, the assessment was considered good between colleagues involved in the same function. However, about a quarter of the respondents considered as regular or bad the relationship with the administration staff, the coordinators of the area, and the human resources staff. The result of the interviews was useful for the ergonomics committee to present various recommendations to the company.

8.5.1.1 Anthropometric Data of the Workers, and Measurements of the Platform Work-Site

The objective of the anthropometric assessment was to record and analyze the incompatibilities between the work-sites of smallest and greatest dimensions, and the operators of extreme dimensions (percentiles 2.5% and 97.5%). Out of this, it was possible to put forward recommendations which meet the needs of the task and the physical restrictions of the workers. By using anthropometric mannequins, the action area and the field of vision of the tallest and smallest user was defined. First, the extreme dimensions of the platform work-site were studied. Next assessments and recommendations were made for the interface zone based on designs with the intersection of the 2.5% percentile person and the 97.5% percentile standing on the platform executing the activity of unloading a truck (Figure 8.8). The criticisms referring to Figure 8.8, with a frontal view in the activity of unloading the pallet were (see the corresponding letters in the figure):

A—The handrail does not begin on the first step which can cause an accident.

B—There is a variation in the height and width of the steps which makes it difficult to walk up and down the steps.

C—Insufficient space for movement during the activity of unloading the pallet, which provokes torsion in the trunk when reaching for the crates and putting them on the conveyor.

D—The access area to the platform is restricted because of the metallic structure of the steps.

E—Misalignment of height of the last step with the platform.

By using bidimensional anthropometric mannequins (smallest and largest size) and considering the biomechanical angles of comfort, interface parameters were defined to cater for the extreme morphology of some of the users at this workstation. These recommendations were obtained using solutions of multiple adjustments, the intersection, or compromise for the field of vision and action area. Dimensional and organizational recommendations were presented for the activities of unloading a truck, the platform, the pallets, the access steps, and the action and visual zones. After the anthropometric analysis, the analysis of the task and the behavior of operators at the platform were undertaken and are described below.

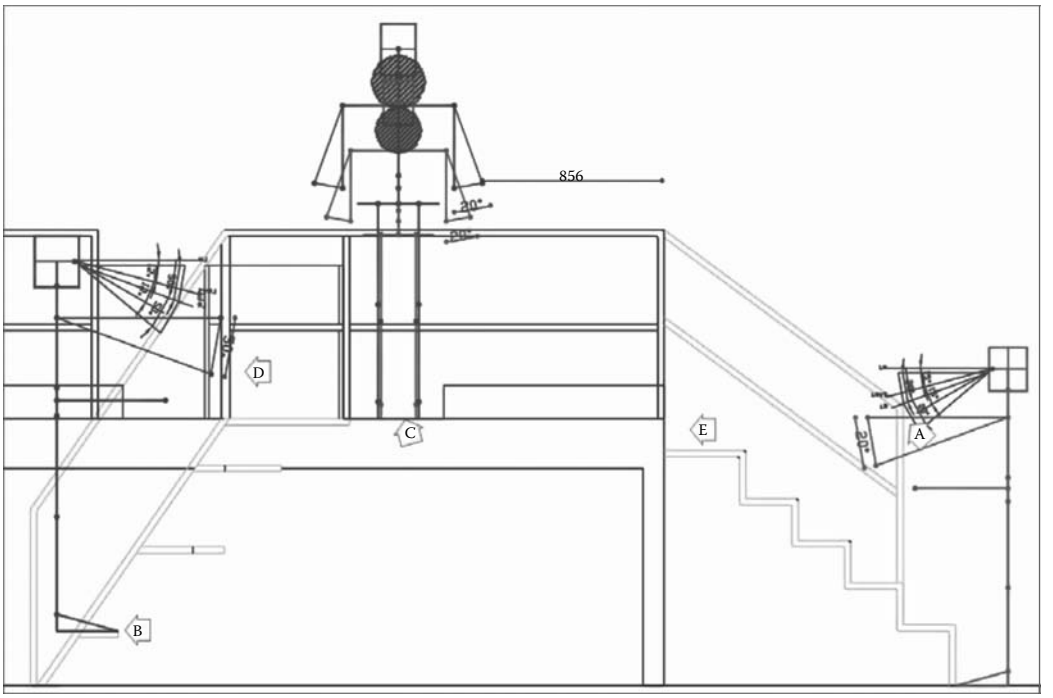


FIGURE 8.8
Front view of the intersection of the 2.5% percentile man and the 97.5% man standing on the platform in the activity of depalletization.

8.5.1.2 Analysis of the Task and of the Behavior of the Operators of the Platform

The demands of the task were investigated using three elements: its content; its implications in terms of getting information and visual requirements to determine action responses; and the manipulation of controls such as levers and switches. Based on such elements, the constraints on the production operators were analyzed using two instruments:

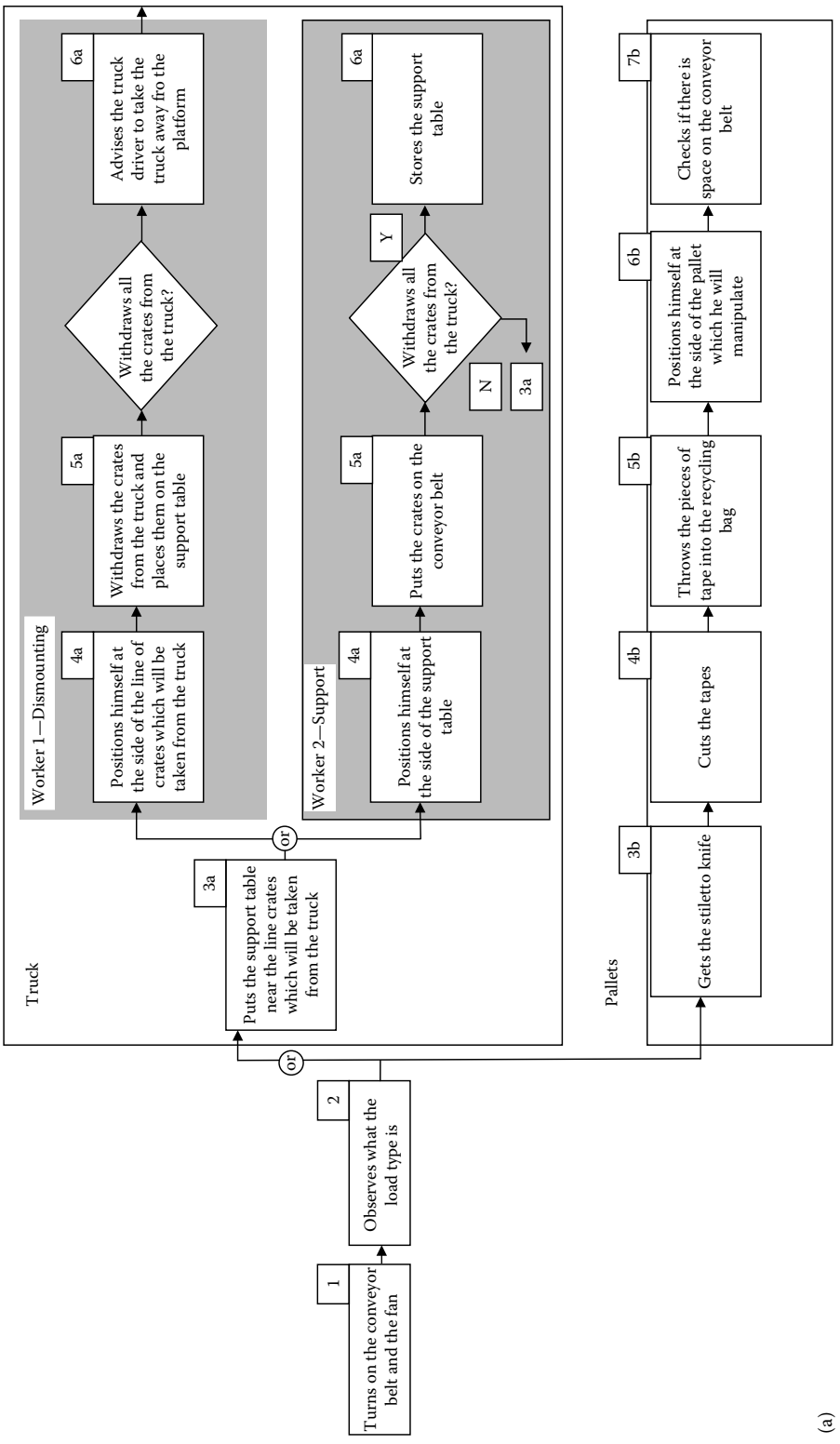
- A flowchart of the activities of the task, which comprised the hierarchical and sequential presentation of the activities performed at the work-site.
- Definitions of behavior and behavioral records of the activities through the WinOWAS tool.

8.5.1.3 Flowchart of Task Activities

This included:

1. *Pretask activities*, which included all the activities before starting the actual task, e.g., meeting with the officer-in-charge, cleaning the area, and like activities
2. *Task activities*, which comprise the actual working activities at the platform
3. *Posttask activities*, which correspond to the final close down of the activities

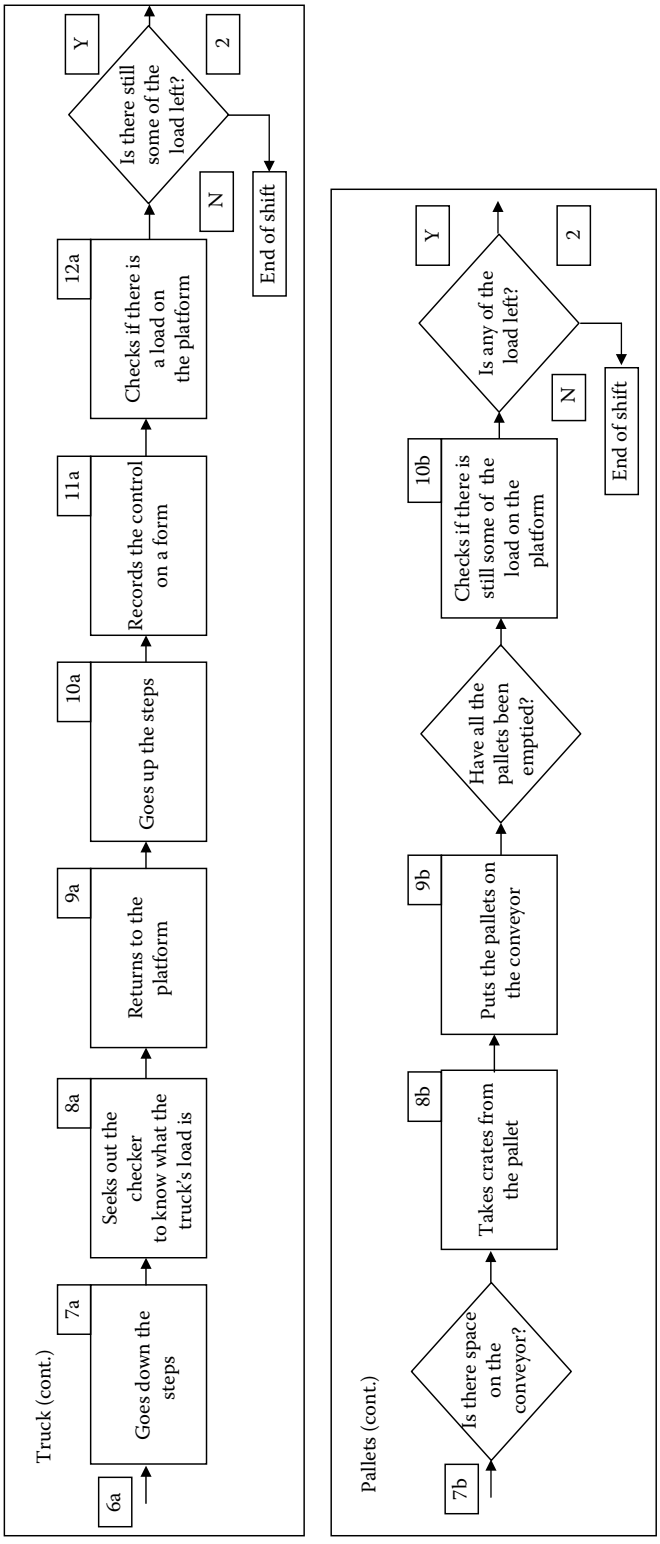
This research instrument allows the task to be analyzed in detail and explains the functions required of the workers. As an example, presented below is a flowchart of the task of "unloading material" (Figure 8.9). Some lessons were learned based on the analysis of the



(a)

FIGURE 8.9
Flowchart of the ordinary activity of the task of "unloading material."

(*continued*)



(b)

FIGURE 8.9 (continued)

flowchart. These involved the form in which programming production and information sheets were passed on to the worker, including the definition of tasks and positioning on the conveyor, since this worker was the person in charge of production control for the truck which is unloaded. Based on analyzing the task, some recommendations were presented referring to pauses, rosters, furnishing of the seat, discussion of the diagrams of the analysis of the task with the ergonomics committee and the workers in order to establish standard procedures for the tasks involved.

8.5.1.4 Register of the Behavior of the Operators of the Platform

After assessing the activities undertaken by operators, the behavioral registers of the task were compiled. In this study, a semiquantitative assessment method used to identify harmful body postures during the working day was chosen, viz. Ovako Working Posture Analysing System (OWAS). According to Long (1993), OWAS allows postural data to be analyzed in two ways: to examine the combination of postures of the back, arms, and legs, to determine their effect on the musculoskeletal system and to examine the relative time spent in a specific posture for each part of the body. The length of each activity cycle was timed. It was observed that, in the normal situation of unloading a truck and of unloading the pallet, the cycle lasted between 1 and 2 s for each operator. Silverstein et al. (1987) characterized highly repetitive jobs as those with a time cycle of less than 30 s (more than 900 times in a working day), or when for more than 50% of the cycle time, the worker performs the same type of fundamental activity where a sequence of steps in the work-cycle is repeated.

The postures were captured on film and later analyzed. The software WinOWAS (obtained from the Department of Occupational Safety Engineering, Tampere University of Technology, Finland, http://turva1.me.tut.fi/owas/) was used to capture and classify the images. WinOWAS software generates the percentage of time spent on the postures stressing the back, arms, and legs. The system was used to analyze the data of the operators carrying loads equal to and above 10 kg. After registering the postures, WinOWAS classifies them into four categories referring to the degree of urgency required to apply corrective measures to reduce harmful postures. The highest indices in categories three and four (the most harmful according to OWAS) were the activities of unloading a truck (13%) and unloading the pallet (21%). In this last category, the physical burden of the posture is clearly extremely harmful. Based on these data, a postural analysis was made which led to the following recommendations:

- Improvements to the work equipment and study on the disposition of equipment in the platform area
- Enrichment of the task so as to minimize the effects of the postural rigidity
- Provide rosters so as to relieve muscular demands arising from the need to assume physically poor working postures

8.5.1.5 Assessment of the Physical Costs to the Platform Workers

The objective of this step of the analysis was that of identifying possible pain and discomfort suffered by the operators in various regions of the body, and determining whether there was any intensification of this pain during the working day. For this step, a sample of 15 workers (nine from the morning shift and six from the afternoon shift) was used. The sample was selected at random from operators on the daily roster of the platform.

The analysis of discomfort, one of the techniques for assessing the physical costs on the work-site, was carried out by means of a scale of subjective assessment to identify the human costs of the work (Corlett and Bishop, 1976). For this, use was made of a numerical scale (from 1 to 5) associated with the expressions which defined the level of pain or discomfort felt at the moment of assessment. The expressions presented were no pain, some pain, moderate pain, great pain, unbearable pain. The extremes (no pain and unbearable pain) were excluded due to the low registers. A figure of the human body was used, divided into various segments, to enable the respondent to specify the regions of the body in which discomfort was experienced. For each worker, three maps of postural discomfort were applied which corresponded to three points of time in the working day: at the start of the shift, on leaving for the meal break and at the end of the shift. The data obtained at the start of the working day were important for trying to identify if the operators have arrived at work already feeling some discomfort or pain.

Figure 8.10 presents the map of postural discomfort with the responses given by the participants who refer to the sensation of pain (1, some pain; 2, moderate pain; and 3, great pain/unbearable pain) and the moments of the working day (start of the shift, leaving for meal break, and at the end of the shift). It can be observed that the lower region of the back, about which there was the highest index of complaints, showed a very significant increase during the working day. Seven percent of the respondents complained of pain at the start of the activities, one third of the sample (30%) complained of pain in this region before the interval for a meal, and 40% had complaints at the end of the working day. The right and left shoulders were the second region with the highest index of complaints, and were distributed as follows: 7% stated they began the working day with pain. This number grew to 40% before the meal break and this percentage was maintained until the end of the working day.

It can be concluded that the high incidence of pain in the regions of the upper limbs and the back, especially the lower back, is the result of a poor design of the work-site. Although the workers were not known to complain, the indices of the pains in the hands, wrists, and forearms, could well be the result of the posture with the arms extended above the shoulders when lifting and transferring a load of over 10 kg. Working with the arms stretched up can cause risks of pain in the shoulders and arms (possibly periarthritis of the shoulders).

It was recommended that:

- Body segments should be maintained as much as possible in a neutral position, so that the muscles and ligaments are more relaxed and subject to less force. Examples of bad posture with segments which are not in neutral position are arms raised to withdraw crates from the last pile of the pallet, twisted wrists on transferring the crates from the support table to the rolling conveyor; neck and head inclined or turned in the inspection of empty liter bottles; trunk inclined and twisted on transferring the plastic crates from the truck and from the pallets.
- Avoiding forward inclination of the trunk where it is more difficult for the muscles and ligaments of the back to maintain the body in balance. This can be verified when the operator reaches for the piled-up plastic crates in order to place them on the rolling conveyor. Maintaining a posture with the trunk inclined causes neck and back pains, besides which working with the arms held up causes pain in the shoulders.
- Avoiding postures with the trunk twisted since these cause pressure on the spine when unloading the pallet.

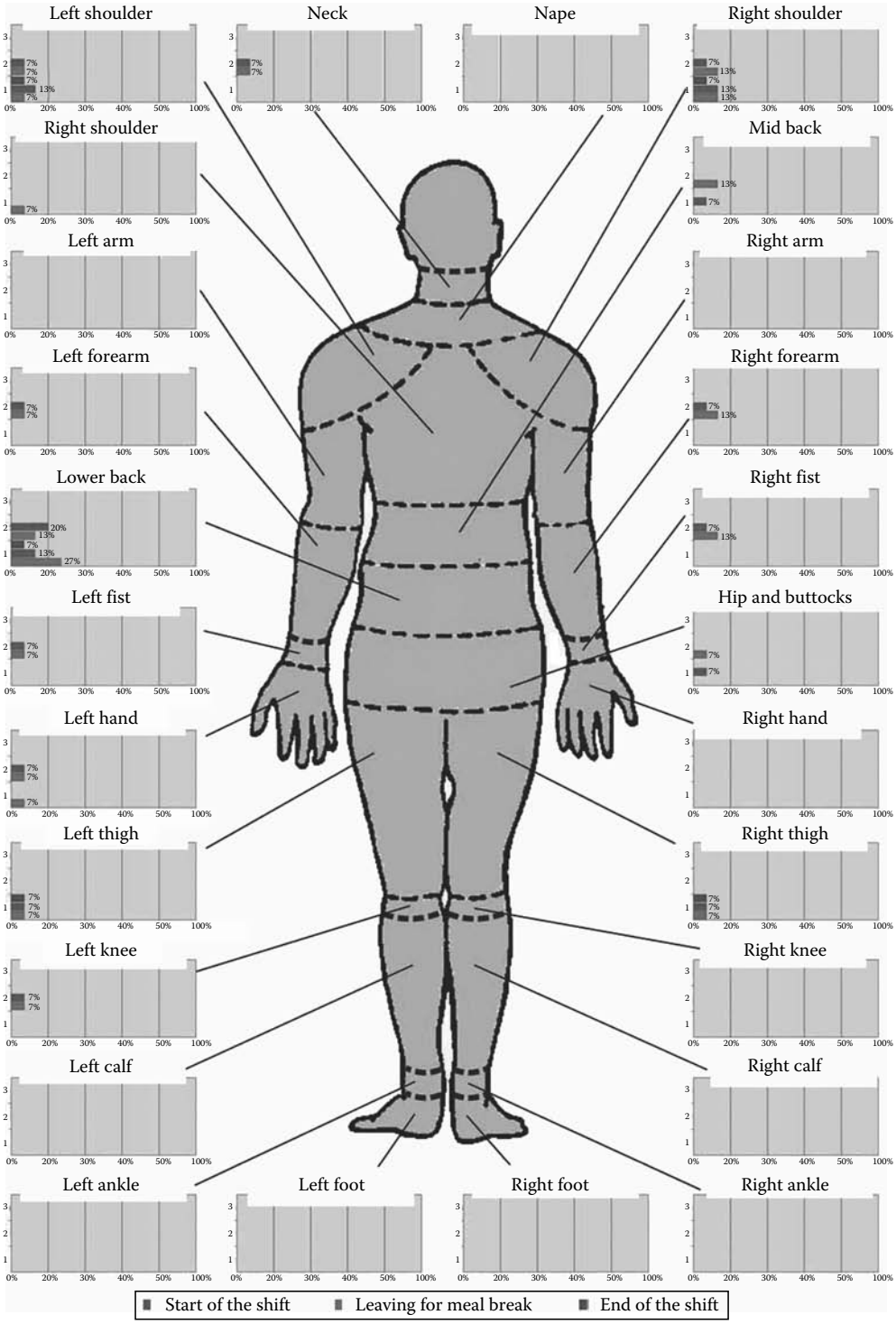


FIGURE 8.10
Map of postural discomfort with information referring to the sensation of pain in the three moments of the working day.

- Alternating postures and movements, for neither a prolonged posture nor repetitive movements should be maintained for long periods of time since they are tiring and can stress the muscles and joints. Preventing excessive repetitive movements of the arms by the use of alternative tasks.
- Including breaks to avoid muscular fatigue arising from the effort caused by repetitive work.

8.5.1.6 Register of the Frequency of Heartbeats

In recent years, cardiac frequency has been increasingly used in Brazil as a measure for assessing workload. One of the main reasons for the spread of this technique is that it is easy to record and store data. Within certain limits, cardiac frequency increases linearly with the work performed, assuming that the work is dynamic and not static, and that it is carried out at a constant rhythm. When the work is light, cardiac frequency increases rapidly up to a level compatible with the effort and can then be maintained constant throughout the working day under "ideal" circumstances. When the working day ends, the heartbeat returns to normal after some minutes for most individuals. Usually, on doing heavier work, however, cardiac frequency keeps on increasing until the work is interrupted or the operator stops because of exhaustion. The analysis of working cardiac frequency is made by comparing the beats at rest (before work) and while the task is being carried out. Kroemer and Grandjean (2005) recommend that the limit for continuous human work when the "pulse of work" is measured should be up to the limit of 30 beats/min (i.e., the difference between working and resting heart rates).

The sample comprised 11 operators from the industrial sector distributed in the two work-shifts (five for the morning shift and six for the afternoon shift). Polar telemetric heart monitors were used to register of the cardiac frequency of each subject at the following intervals:

- Before the start of the working day, allowing for a 15 min rest after the moment of arrival at work. The waiting time is justified to allow for the heart to "slow down" after commuting to the place of work.
- At 20 min intervals while the activity was carried out (unloading truck, unloading the pallet, inspection of the cases, support in unloading the truck, and so forth). These data were later analyzed as a way of identifying which of the activities generate the greatest physical effort.

Figure 8.11 presents the cardiac frequency in accordance with the activities performed on the platform. Using averages, the activities which produced the lowest values are "rest" (85 beats/min), "inspection" (91 beats/min), "return from break—immediate" (95 beats/min), and "leaving shift" (95 beats/min). The activities which produced the highest average values are "leaving for break" (101 beats/min), "others" (101 beats/min), "support to unloading the truck" (111 beats/min), "feeding the transport" (113 beats/min), and "unloading the truck" (154 beats/min). It was observed during the activity of unloading the truck that the cardiac beats varied on average 69 beats above the reference value at rest (85 beats/min). In the other activities, this value remained below the 30 beats, which is deemed acceptable for the performance of a work activity.

Using this analysis, the activity on the platform can be considered as heavy work. According to Kroemer and Grandjean (2005), heavy work is any activity that demands great physical effort and is characterized by a high consumption of energy and great

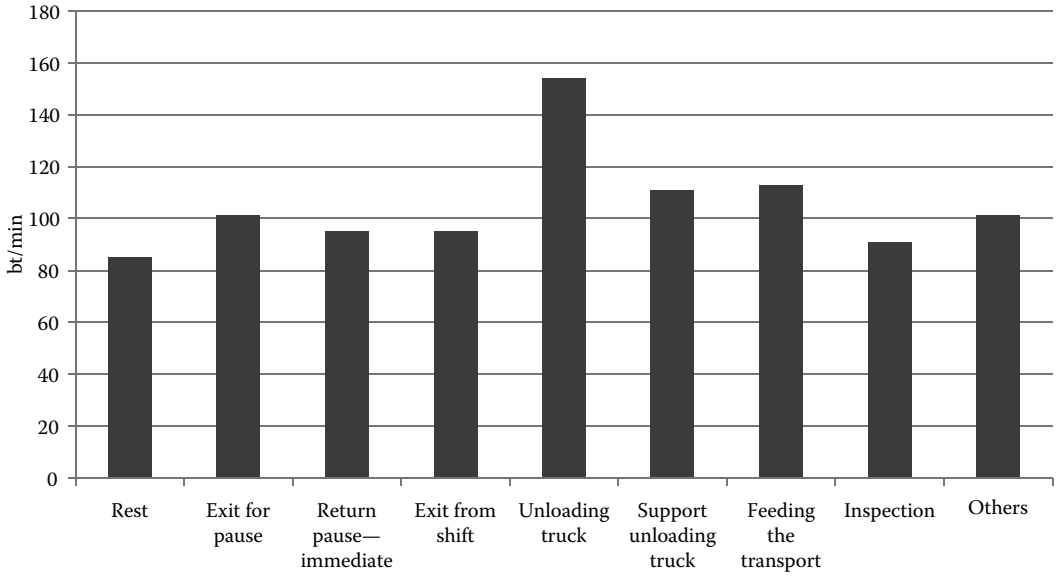


FIGURE 8.11
Frequency of heartbeats in accordance with the activities undertaken on the platform.

demands on the heart and lungs. The consumption of energy and the cardiac effort impose limits on the performance of heavy work, and these two functions are generally used to assess the severity of the physical work. The jobs which involve carrying weight were considered as the heaviest forms of work. From the results achieved, it was evident that an adjustment of the operations was required. A recommendation to use a roster among the platform workers was made. Thus, more suitable scheduling of unloading of trucks and pallets was suggested, that is, creating a schedule which makes it possible to have a regular turnaround of the operations undertaken on the platform, allowing for a rest period for the muscular group which had been used in the previous operation, and thus avoiding the physical exhaustion of the operator.

Monitoring the rhythm of work was also recommended, for it was observed that the operator's work pace on the platform was very intense. This exacerbated the physical overload, due to the high degree of osteomuscular stress, as well as the psychic effort, due to the stress generated by the pressure of deadlines stipulated by the logistics. Working at such a pace is likely to lead to work accidents, and product loss. As a consequence there needed to be a reduction in the rhythm of production, as well as to allow spontaneous short pauses (initiatives taken by the workers themselves to interrupt the activity), or disguised pauses by doing easy and routine activities such as tidying up a bench, seeking the officer-in-charge, and so on.

8.5.2 Implementation of the Ergonomics Recommendations in the Platform Work-Site

The ergonomics program developed several recommendations for the platform work-site. These were grouped into short-, mid-, and long-term solutions and below are some of the recommendations implemented by the company:

- A model of rotating duties among workers was instituted with a view to lessening the physical stresses inherent in the task.
- A new support system was tested to facilitate the unloading of trucks.
- A useable working area was defined at the rolling conveyor for the unloading of cases which takes into consideration the subsequent processing time of the unpacking machine. All this aimed to minimize bad work postures and to institute microbreaks in the activity schedule without having an impact on the productivity of the sector.
- A project was drawn up for the exchange of some pallets which were unsuitable for some tasks.
- The platform was reconfigured because of the insufficiency of space for off-loading the pallets.

8.6 Conclusion

It is not always feasible for companies to make financial resources available for ergonomics intervention. This is all the more so when the situation is one of forming an in-house ergonomics committee for although this is a slow ongoing process it certainly is one that lasts longer than an intervention conducted only by consultant ergonomists.

The studies presented have served as an example for implementing an ergonomics program with the help of an *in situ* ergonomics committee. It is important to make clear that the objective of the methodology applied in the company was not only to intervene in the work tasks by making them more acceptable for the workers, but also to acknowledge the fact that the solutions proposed by an ergonomics team can provide an improvement in the quality of life for the staff, as well as improve productivity. Nevertheless, experiences undergone in different companies, and corroborated by the study presented in this chapter, indicate that conventional interventions, when conducted without the effective participation of the workers, may very often fall by the wayside with the passage of time, when the modifications are no longer seen as constituting a novelty.

The jobs adjusted in this company generated very positive results. We highlight the fact of the company's administrative staff being part of the ergonomics committee, which lent a certain autonomy to the group when managing resources and people were also involved. The systematic meetings with the groups generated requests which were passed on to management in a participative way. At each conclusion, the information was sent on to the workers themselves so that they might validate and propose changes. It is also important to draw attention to the readiness of the company to release workers to participate in all the meetings of the ergonomics committee. This only occurred because of the commitment of the company's management to the ergonomics program. At some point in time, the company was under audit, which limited or even impeded the work of the ergonomics committee. Nevertheless, it is worth noting that, although it may be perfectly possible to adjust the method of ergonomics intervention to the needs of each company, it is important to observe the corporate identity of each company, taking into consideration its potential and its limitations.

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Part III

Diverse Ramifications

9

Ergonomics of Technology Transfer

Houshang Shahnavaz

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9.1 Introduction

Throughout human history, the main use of technology has involved the transforming of natural resources from the earth into usable physical commodities. Technology, originally concerned with improvement of traditional craft techniques and subsequently with the application of abstract knowledge to practical problem solving, has led societies to a bright and prosperous future. The level of technology development has served as an indication of the general progress of social development. Countries are judged and classified according to their level of technological sophistication. However, although technology was created as a means of promoting the health and welfare of humans, it also has another side, which is a considerable threat not only to human physical and psychological health, but also to the very survival of humanity.

Technology transfer has a long history dating many thousands of years back, when knowledge and products were transferred from Asia to Europe (e.g., the Silk Road trade), and later from Europe and the United States to the rest of the world. Through globalization the cooperation and connection between different countries is nowadays tight and close, and multinational companies are operating all over the world. Products developed in one country are now sold and used globally; thus many countries are trying to develop their own specific products or technology in order to gain entry into the global market.

9.2 Advantages of Technology Transfer

With the limited resources of a country (both man power and material), technology transfer is a very helpful process to meet the basic needs of individuals, societies, and countries. Basic individual needs include food, clothing, shelter, sanitation, and care. Other individual needs include those for pleasure, enjoyment, easing of tasks (equipment and machinery); the need for independence (DVD and stereo); for comfort, safety, fun, and sport; for enlarging our range for travel (car, bicycle, boat, and aircraft); and the need for self-fulfillment (education and information). Societal needs include providing of infrastructures (roads, airlines, communication, energy); providing of institutions (education, research, training, waste disposal, administration, and organizational structure); and the providing of capital goods (buildings and machinery). The needs of countries include provision of power and security, of defense technology, of commercial power (market power and prestige), provision for the internal security of the state (crime detection and prevention), regional development (like roads, airports, railways, universities, and research institutes), providing employment, environmental protection (like technology to detect and prevent environmental pollution), and providing protection of people (safety and health technologies). No country today is able to develop and manufacture all the various aspects of technology needed by that country. In areas where the country has not sufficient capability and resources to develop its own indigenous technology, appropriate technology transfer is an effective and easy way to satisfy these needs and create economic development and progress.

A healthy manufacturing industry is essential to the economic health of an industrialized nation and its progress. Technological innovation has contributed significantly at both micro- and macroeconomic levels. At the microeconomic level, innovation determines competitiveness and growth, and the competitive position of the firm through production technology. At the macroeconomic level, it determines the competitive position of the whole industrial sector nationally and/or internationally.

9.3 Disadvantages of Technology Transfer

Technology is a double-edged weapon, with both positive and negative aspects. Improper use of technology as well as use of wrong technology (e.g., not fitted to user demand and characteristics), creates problems and causes work-related accidents and injuries resulting in decreased quality of life. Another potential risk is transfer of inappropriate technology which results in inefficient technology utilization, causing low productivity and decreased income for the company. Technology transfer can also create mass unemployment and

diverse social problems, destroying the social structure of the community or the country, and it can pollute the environment.

Modern technology may affect the environment in many ways that are not yet fully understood. In many parts of the world, the environment is attacked by excessive use of chemicals and by the waste of technology. Modern technology often has the potential to cause infinite damage and harm both to the environment and to humans. The complexity and size of modern technology is a potential human risk which has been shown in disasters like the Carbide pesticide plant in Bhopal, India (1984), the nuclear plant accident at the Three Mile Island, Unit 2, in Pennsylvania, USA (1979), and the Chernobyl nuclear power plant disaster (1986). Apart from these cases of accidents, modern technology can be described as violent based on the day-to-day methods of production. The large-scale dumping of chemical wastes that occurs in spite of attempts to control it, destroys the environment. The major detrimental effects which cause instability of the environment usually fall into the categories of resource deterioration, biological pollution, chemical pollution, physical pollution, and social disruption.

9.4 Development in Industrialized Countries

Traditionally, the aim of technology transfer has been to ensure that the imported technology contributed maximally to the technical progress and economic development of a country. Development has mainly two important goals. The first is to remove extreme poverty by providing basic needs of food, shelter, health care, education, and employment. The second is to provide modernization and growth of the country (National Research Council, 1977). In industrialized countries, their technological development has contributed to economic growth, social progress, and reduction of many sources of accidents, injuries, diseases, and stresses. It has offered new and more effective preventive and treatment methods, and new opportunities for a high quality of life. Rapid technological development in the spheres of education/training, social sciences, work environment, and health and safety has developed all sections of the society. Proper use of the economic growth has been widely responsible for social progress and better quality of life. The wealth of these countries is primarily the product of application of technological knowledge, democracy, and a stable political situation. With gradual industrialization and the evolution of technology, appropriate social structures for dealing with the consequent problems of industrialization have been established. Additionally, a safety culture has been rooted in those societies as a result of strong labor unions and cooperation between employees, employers, and governmental institutions.

9.5 Current Situation in Industrially Developing Countries

Of 191 countries in the world, about 150 are industrially developing countries (IDCs) with more than 75% of the world's population. They have 75% of the world's natural resources, but account for about 15% of the world's production. The demand for water, food, housing, and services in the world has increased by 200% from 1980 to 2000, while the fertilized soil

in IDCs has decreased in the last 30 years by a third (Shahnavaz, 2000). As a result, around 1 billion people are undernourished; about 14 million people die every year from hunger, half of them are children. Industrialization in some IDCs has caused resource deterioration, biological pollution, chemical pollution, physical, and social disruption.

In many IDCs the adverse side effects of technology are more pronounced than its advantages. These countries have tried to achieve economic growth and development by importing technology, both hardware and software, usually designed for the producer of the technology, i.e., the industrialized world. Due to many differences such as the morphology of people, different technical levels, different environmental conditions, different cultural and socioeconomic situations between the producers and the recipients of technology, the policy of "blind technology transfer" has not always been successful.

In contrast to industrialized countries, the society and social services in IDCs are unable to effectively adapt to the changes that technology has brought. Additionally, a safety culture does not commonly exist. Further, general poverty with unsatisfactory living conditions, lack of transport systems, lack of proper national health care, lack of labor support systems, and problems associated with urbanization and the creation of shanty towns have all added to the overall unsatisfactory conditions. Inappropriate technology transfer and rapid change have caused considerable health and safety problems, poorly designed work processes and operations, poor working environments (noise, heat, air pollution, vibration, and heavy load), low utilization of the technology, low productivity, low motivation levels among the workforce, poor worker satisfaction, high rates of personnel turnover, especially among the skilled workforce, high physical and mental stress levels, and a host of associated social problems and tensions. Further, harmful working methods, such as working unprotected with dangerous materials and using improper tools and unsafe equipment, have resulted in a high frequency of work-related accidents, injuries, and diseases. According to Elgstrand (1985), the aim should be to break this vicious circle of failure (Figure 9.1) by creating safe and satisfactory working conditions and promoting the health of workers by preventing occupational accidents and diseases, and reducing unnecessary fatigue. All these measures would ensure proper utilization of human resource capabilities and thereby promote increased productivity (Shahnavaz, 1987). It should be

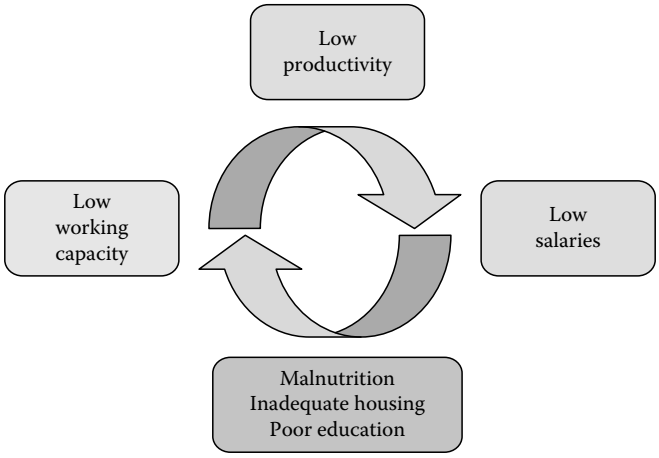

FIGURE 9.1
A vicious circle of events typical of IDCs.

noted that sustainable development will only be achieved by using proper technology, enabling a balance between three substantial components (3 Es):

- *Economy balance* (satisfying basic needs of people and creating equality)
- *Ecology balance* (achieving environmental balance and environmental protection)
- *Energy balance* (proper use of human resources and materials)

IDCs should aim to strengthen their autonomous capacity for creating technology at home to achieve a cost-effective self-reliance which meets their own economic and technological needs through their own effort, in harmony with the sociocultural and environmental characteristics of the country.

9.5.1 Criteria for Selecting Technology

Technology is the sum of knowledge, experiences, skills, and techniques necessary to manufacture a product, perform a task, and/or establish an enterprise for this purpose. It is the capacity of the firm or the country to create, select, and use various technical solutions to best solve its problems and be prosperous. Technology is therefore not wholly transferable, but must also be developed locally. Technology is usually categorized into hardware and software. "Hardware" means, for example, machinery, equipment, tools, accessories, instruments, buildings, civil work, and material. "Software" includes information, planning, programming, management, education, training, documentation (instruction and manuals), computer programs, services, maintenance, and data.

Technology should be considered as a process, consisting of phases of innovation. In these phases, the choice and changes are made depending upon socioeconomic interests, and social and cultural values. Müller (1987) defined these phases as:

1. Basic research related to all four elements of technology, i.e.,

   Technique: which consists of the instruments of labor (machinery and tools), material, and the way they are brought into function by labor in the working process.

   Knowledge: which is made up of three fundamental categories: applied science, skills, and intuition in varying proportion depending on the individual characteristics of the relevant environment.

   Organization: for making technique and knowledge productive.

   Product: the technique, knowledge, and organization culminating in the product.
2. Theoretical development of specific technology. The focus is on the knowledge element.
3. Application of knowledge to technical solutions. The focus is on techniques.
4. Concrete organization and diffusion of the function and use of technology. The focus is on organization.
5. Consumption of the end-product of the technology. The focus is on the product.

Technology transfer means a process of translocating a technology (developed and adapted to a certain place and country and under certain conditions) to another place and country and under different conditions. There are many types of technology transfer such as direct foreign investment (package transfer and turn-key arrangements), licensing arrangements,

franchising, joint ventures, daughter company, through foreign aid (sister industry program), and item transfer (hardware and/or software). Technology is usually transferred as a package of hardware and software, a so-called system transfer. A system is an entity that has both interdependent parts and purpose. For the success of the whole system, all parts should work properly. According to Stewart (1978), an important feature of technology transfer is that the technology is useful for the country. She based her analysis on an equation of the relationship between the world technology (all known technologies) and the technology available to the country, and narrowed it down to the technology which is useful for the country. She pointed out that technology consists of a series of "techniques." The technology available to a particular country is all the techniques they know about (or may, with not too much difficulty obtain knowledge about) and could acquire, while the technology in use is the subset of techniques the country can acquire. It must be noted that the techniques available to a country are not easily identified. A weak communication between the technology receiver and technology suppliers may mean that the recipient country only knows about some of the total technologies available, which constitutes an important limitation when selecting a technology. On the other hand, technology may be known but may not be available because no one is producing the machinery or other inputs required. Stewart (1978) draws the following conclusion, that if the technology in use is thought to be inappropriate, it may be inappropriate because the world technology is inappropriate, or because an inappropriate subset is available to the country, or because an inappropriate selection is made, or some combination of the three. Confusion is caused by failing to distinguish between the three. Her equation is described in Figure 9.2. The technology in use is therefore a combination of the world technology, the technology available to the country, and the choice of technology. Lind (1986) developed the second half of the figure and considered that "… inappropriate use of technology does not only require a selection to be done but also adaptation to technical as well as socio-economical environment." By "nonadaptable techniques" he means the situation where certain technical characteristics are not suitable to the technical conditions or where the organizational requirements to manage the techniques in question cannot be fulfilled within the existing socioeconomic infrastructure (Lind, 1986) (see Figure 9.3).

According to Wisner (1984) technology transfer can be described as inappropriate in the following three situations:

Incomplete: When not considering all aspects of the technology in the transfer process, i.e., leaving out the transfer of maintenance organization and just concentrating on machinery.

Imperfect: When user characteristics are not considered in the technology transfer process, i.e., not translating maintenance manuals and instructions to the users' language, or not considering the operators' physical and mental characteristics nor the limitations in the design of technology and workplaces.

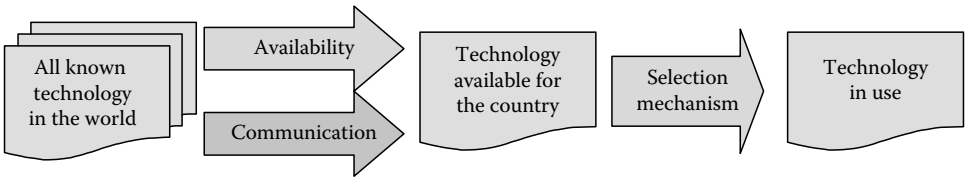

FIGURE 9.2
The world's technology is narrowed down to the technology in use depending on availability of the technology to the country and the degree of effective communication.

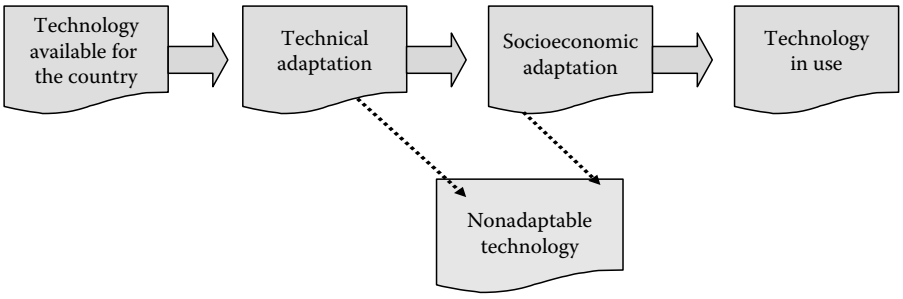

FIGURE 9.3
Selection mechanism of technology in use.

Inadequate transfer: When the environmental conditions of the recipient country are not considered in the design of the technology. For example, transferring of personal protective devices made for people in cold climate regions to be used in a tropical climate, and by people of different size and shape.

The large varieties of circumstances which exist in the countries of the world highlight the need for different development strategies and the selection of alternative technologies. Appropriate technology is not a general concept but, considering the immense variety of circumstances that exist in IDCs, it is true to say that each instance is a special case. The crucial issue which should be fully considered for successful transfer is to identify which technology to acquire, how to transfer it, how to adapt it to the future users and its operating environment, how to operate and maintain it, and how to build upon it in order to achieve the goals of the technology transfer. However, in reality, the choice of technology in any specific situation is to a large extent conditioned by the social, economic, and political structure, as well as the vested interests and power of different actors and social groups that determine the choice of technology.

9.5.2 Ergonomics Considerations in the Transfer of Technology

Ergonomics knowledge and considerations in the design and transfer of technology would make sure that the technology is appropriate for use in its operating environment, and that the technology is safe and productive. An appropriate technology is one which is suited to its user population and to the environment in which it is used. Technology transfer in the broader sense is a means by which a country undertakes to change circumstances and satisfy needs. It is therefore not the objective of development, but rather a principal means for attaining the required development.

Technology transfer with the following general characteristics is considered to reflect good ergonomics and to be appropriate for use:

- It is consistent with the country's needs and resources.
- It is sensitive to the operating environment.
- It is adjusted to the local level of education and the social, cultural, infrastructural, economic, and political conditions of the people.

However, it should be noted that appropriate technology differs according to place and stage of development, local conditions, and local infrastructure of the importing country.

Further, technology which was initially good may not be appropriate at a later time and/or at different place due to different/changed surroundings, different/changed objectives or both.

There is a general consensus that the characteristics of technology are largely determined by the prevailing conditions of the technology-producing country and usually reflect the income level, resource availability, resource costs, and organizational system in the country for which the technology was originally designed (Farhang, 1993). When such technology is transferred from an industrialized country to an IDC of different characteristics some adaptation is needed to use the transferred technology more efficiently. For proper and efficient operation, optimal harmony and good fit should be created between all factors of the system in its new environment. However, due to reasons of costs and lack of demand from IDCs, companies producing the original technology very seldom take the initiative to adapt their technology to the conditions of recipient countries. Consideration of ergonomics in the transfer process would ensure that many contributing factors for successful transfer are taken care of in order to achieve optimal human performance, higher productivity, and improved health and satisfaction of the workers. These factors include issues at both micro- and macroergonomics levels. At the microlevel are issues such as user population anthropometry, work capacity, functional ability, work environment conditions, and cognitive and cultural characteristics which should be taken into consideration to create optimal user–machine–environment interfaces. At the macrolevel the issues involve securing proper organizational design and management systems, a good communications network, and worker participation and involvement to ensure optimal utilization of the technical and personal subsystems.

Successful transfer of a technology from a firm in an industrially developed country to a firm in an IDC depends on the decisions taken by both the technology supplier and the technology receiver, as well as the extent of dynamic interaction and communication between the two partners. Further, the environment surrounding the technology transfer is another major consideration in the process. The environment influences the development of a particular relationship between the partners and the opportunities for selection of the appropriate technology. The success of the process is determined by the cooperation between partners which will be developed during a long-term contract. However, it should be said that the ultimate responsibility for a successful transfer process rests with the technology receiver. Regarding the appropriateness of the transferred technology, the level of ergonomics awareness by the technology supplier and receiver firms, as well as their commitment to ergonomics design and application, will generally influence their decision. If their awareness and commitment to ergonomics is high they will select an appropriate technology and try to adapt it to the local conditions of the recipient firm. The better the ergonomics conditions of the firm and the stronger the commitment at micro- and macroergonomics levels, the better the choices and utilizations of technology in its new environment (Figure 9.4).

It is generally agreed that three characteristics of the technology recipient's environment are decisive for successful technology transfer. These are government policies, technical absorptive capacity, and cultural differences (Robinson, 1989). The ergonomics issues, both at micro- and macrolevels, which should be considered in the government politics include proper assessment of the country's needs and requirements with regard to the nature and type of technology. Of further importance is the establishment of relevant research and training institutes, and supporting organizations for promotion and implementation of safety and ergonomics at work. Further, government policies for proper utilization of technology include establishment of support organizations for local

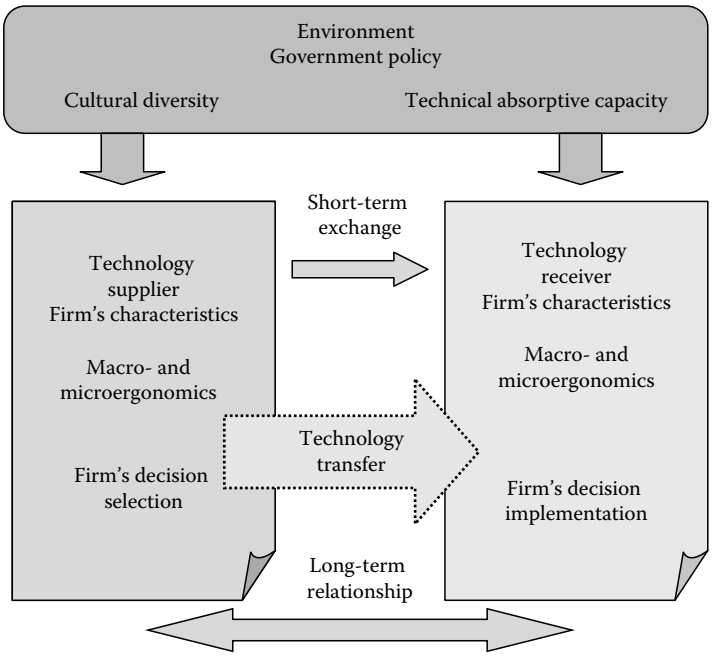

FIGURE 9.4
Technology supplier and receiver, decision making, and acting.

industries, networking, documentation of national statistics and databases, as well as formulation of recommendations, promotion, control and implementation of ergonomics, health and safety at work. Since many factors influence the nature, extent, and diversity of technology transfer problems in different countries, it is necessary for each country to make research and training an indispensable part of its industrial development policy. Likewise, proper legislation and inspection routines play a significant role in encouraging factory managers to consider ergonomics issues at work, thus creating safe and healthy work environments. The macroergonomics actors such as the government, business organizations, and organized labor are the major determinants of the success of ergonomics activities in small groups within an industry. In the context of absorptive capacity one of the main ergonomics issues in IDCs is the absence of, or shortage of, scientific and technological infrastructure and training facilities for improving the level of education and skills of the workforce for safe and efficient operation, maintenance, and development of the imported technology. Further, employees should be able to assess the risks and side effects of the imported technology and have sufficient knowledge and skills to minimize the risks at work. To support local industries, the country has to improve its absorptive capacity and adjust its infrastructure to the requirements of new technology so that local institutions are able to develop solutions for improvement and promotion of health, and define regulations and guidelines for hazard prevention.

It is documented that transferred technology in many IDCs eventuates in low volumes of production and poor product quality. This is mostly due to a "misfit" between the technology, the technology-user, and the operating environment. In order to create better harmony in the system, macro- and microergonomics issues should be considered for improving the absorptive capacity of the country and firms. At a microergonomics level,

by designing proper workplaces that ensure good fit between the operator and the technology (machines, tools, equipment) and creating acceptable working environments (climate, lighting, noise, clean air) the absorptive capacity of the recipient firm will be improved. At the macrolevel, issues dealing with proper organization, the labor support system, better communication and the network system within the firm and externally, the absorptive capacity of the firm would be improved and utilization of the technology would increase. These are important issues, since the technology is better absorbed in a local environment if it is in harmony with its users and its operating environment. A healthy and satisfied operator is a productive operator who is committed to the goals and objectives of the firm. The following factors have been mentioned for improving absorptive capacity: the level of general education and skills, the ability to identify factors of planning and implementation, market research and feasibility studies, good communication, appropriate legislation and enforcement, good coordination, good general infrastructure, and proper physical facilities. However, in many cases the necessary ergonomics information and knowledge for making the right decisions with regard to technology selection or its proper utilization does not exist among most companies in IDCs. In such cases, assistance can be obtained from an ergonomics consultancy or a research organization. A well-established support system for providing ergonomics information at a national level would ensure proper selection and utilization of the imported technology.

Regarding cultural differences, the national culture of the recipient country and its similarities with the producing country greatly influences the success of the transferred technology. Cultural values, social organizations, and behavioral patterns have a direct bearing upon people's willingness and ability to adapt and absorb technology (Baranson, 1969). A successful transfer of technology requires therefore that the cultural barriers are overcome and cultural issues are considered in the process of technology transfer (Kedia and Bhagat, 1988). In technology transfer, the effect of cultural and religious beliefs and customs can be wide and complex, and difficult to identify significantly. Attitudes resulting from cultural influences can affect technology transfer in the following ways (Shahnavaz, 1991):

- General attitude toward one's job, especially with respect to the female population. In many Islamic countries some types of jobs are regarded as inappropriate for the female population, including night shifts, heavy jobs, and working in a male-dominated environment.
- Attitudes toward jobs. Some kinds of jobs in IDCs are given low status. For example, jobs that make the worker's hands dirty are considered as low-status jobs.
- Attitudes toward organization and working habits. People in traditional societies are likely to find it difficult to adapt to the safety culture, discipline, time schedule, and organization of modern mechanized industry.

Cultural variables in relation to various types of work raise significant issues. Many studies highlight the cultural parameters of human performance (Kaplan, 1991). The failure of optimal use of a certain type of technology is often due to differences in social and cultural factors between the transferee and the recipient firm. However, it should be noted that there are no differences in the basic cognitive capacity or in the psychological capacity to absorb technical training of people belonging to different races or ethnic backgrounds (Wisner, 1983).

A recommended strategy for dealing with ergonomics issues in IDCs, especially macroergonomics issues, is to find familiarity between the ergonomics principles and the

sociocultural values in the society. As the sociocultural issues are complex to deal with, it is better to find a link between the ergonomics principles and the accepted norms and values in the society for easier implementation of the theoretical findings. For example, in Islam, consultation in problem solving is recommended. This statement can be used as a fundamental argument for participatory ergonomics and a basis for organizational reform in many traditionally managed companies in the Islamic countries. The author has been successful in improving several organizational systems in Iran and creating participatory ergonomics for improving working condition and productivity without experiencing difficulties in getting acceptance from management. Another good example of using cultural beliefs and values of a society for better implementation of management procedures is the Japanese "seven tools" technique for quality control. The "tools," which are actually a set of check sheets, diagrams, and graphs, are combined and named seven tools (*nanatsu dogu*) because of the positive connotation: seven tools is the minimum weapon and equipment complement which a samurai warrior carried when he went fighting. The quality control circle (QCC) pioneers named the basic tools required for quality improvement seven tools, a familiar term to everyone in Japan, in order to involve all employees in the quality orientation toward work at Japanese workplaces (Lillrank and Kano, 1989).

9.5.3 Selecting Technology for Industrially Developing Countries

From the various views of what should be considered as an appropriate technology it is possible to identify certain characteristics. The major characteristics of technology which should be considered in the process of technology transfer for ensuring its appropriateness are:

Satisfy local needs: Technology should assist in providing the basic needs of the population concerned, such as a basic standard of living, good working and living conditions, and possibilities for improvement in the quality of life.

Use local resources: Technology should consider both hard and soft elements of the local environment such as availability of natural resources for running the technology and, if possible, use of local resources. Further, it should consider the availability of required infrastructure for effectively operating the technology and the access to energy. Additionally, it should consider the level of education and skills needed for operating and maintaining the technology.

Create employment: IDCs usually have no shortage of labor, especially unskilled labor. The technology should therefore provide enhanced employment opportunities for the local population.

Consider environmental conditions: Technology should focus on long-term economic benefits to the region, on safeguarding the local environment and on protecting local resources. Focusing on short-term benefits would harm the sustainability of local development.

Have evolutionary capacity: Technology should be considered as a dynamic process with evolutionary capacity for improvements and adjustment, as well as potential for keeping it up to date by building upon it.

Based on the past unsatisfactory experiences of technology transfer to various IDCs, the literature proposes the following criteria when selecting appropriate technology for a particular group and in a specific environment. It should be noted that these criteria are very general and should be considered according to the situation in question since not all of these criteria may be relevant for a specific case.

Be low energy intensive (technology should minimize energy consumption): Energy cost is very high and climbing and most IDCs are forced to import energy. As energy cost is

a big proportion of the product price, the manufactured products will have difficulties to compete on local or global markets in a free-trade environment if production energy cost is high.

Be labor intensive (technology should absorb units of labor efficiently): IDCs have plenty of labor and thus it is important that the new technology does not create unemployment, but rather fosters opportunities for work and progress.

Be efficient and productive (technology should produce the intended level of output in the new environment): The local environment in the IDC where the technology should operate is usually very different from the environment in which the technology was developed. It is therefore of vital importance that all aspects of the local environment such as climatic conditions, road conditions, human resources, and safety culture conditions are taken into account before the final decision on technology purchase and transfer is taken. There are numerous examples of technology failures in IDCs due to extreme heat, shortages of skilled manpower, insufficient energy supply, or unavailability of spare parts, to name a few.

Be ecologically stable (technology should preserve the local environment such as air, water, soil): Many IDCs are paying a high price in terms of health problems due to adverse side effects of the imported technology. For example, during the process of industrialization, rapid technology development has led to cases of environmental damage in many countries. In some cases, water, soil, and air have become so polluted that people could not use their own local resources. In such cases, it may be prohibitively costly and time consuming for the country to repair the damages.

Be low cost (technology should be affordable for the country). Most IDCs have limited material resources, limited foreign exchange, and poor economies. It is an advantage if the technology is not too complex because complex technology is more costly and more demanding.

Use local materials (technology should utilize local resources). The technology will be less dependent on external conditions and have more chance for survival in the long term if imported technology uses local resources. There are several negative examples of technologies which were dependent on raw materials or expertise from other countries. Due to changes within the country, or changed conditions in the world, it was not affordable and sometimes not possible for the firm to continue purchasing the needed raw materials or expertise from abroad. As a result they were forced to close down.

Be rural-oriented (technology should be geared to rural adoption, i.e., for people with lower levels of skill and income). It is more feasible for the technology to survive if local, usually rural, people can operate it and can afford using it.

Reduce income disparity (technology should be capable of reducing income disparity in the community or country). In some IDCs, technological islands have been developed where people inside these zones have a much better economy than the general population outside. Thus, technology has created a dual economy in the region causing many social problems and tension. According to Schumacher (1973), dual economy has an unhealthy and disruptive tendency with two different patterns of living at opposing ends of the scale, within the same society. In cases where most of the development effort is put into the big cities and the modern sector of the economy where only a minority of the population is living, the majority living in rural areas and small towns are bypassed. Good examples of technological establishment with the whole community in focus are factories which have extended services to the entire community by creating schools, parks, training facilities, child and health care, and thus made the company part of the whole community. In this way, the company receives more prestige and recognition by the local population.

Be small-scale amenable (technology should be able to be adapted for small-scale production). Small-scale technology operating in rural areas usually provides local employment and prevents migration, which is a cause of many social problems in DCs. Small-scale technology is also less complex, which means it is less dangerous, and more manageable by the local population.

Be learnable (the technology in question should easily be mastered by those using it). It should demand no more than the level of expertise available in the country or, it should be possible to easily train local people in operation and maintenance.

Other factors which can be mentioned for selecting an appropriate technology for use in IDCs are

Be livelihood oriented: The technology should eventuate in an acceptable standard of living for those using it.

Be population stable: The technology should not force people to migrate.

Be socioculturally stable: The technology should not affect sociocultural conditions negatively.

Have a societal effect: The technology should contribute to more than one sector of society.

Leadership promoting: The technology should be capable of promoting participation and creativity.

Be dependable: The technology should be reliable and efficient.

Have investment appeal: The technology should attract donors, government, or private sector investors.

9.5.4 Factors to Consider When Transferring Technology

There are many factors which should be attended to when bringing new technology to a new location. Among them the most important ones are:

The installation site of the intended technology. Provision must be made, for example, for access to water, energy, and communication. Examples abound in which technology could not be brought to an intended site because roads and bridges leading to the site could not withstand the weight of imported machinery to be installed.

The orientation of buildings, walls, and windows. Most IDCs have a problem of heat. To create working conditions in which operators feel comfortable enough to be able to do the job, it is necessary to provide acceptable ambient conditions. Trying to improve the condition via further technology, such as by using air conditioning, is very expensive and not always possible. It is therefore necessary to design buildings to dissipate heat from the surroundings and to shield out direct sun while providing natural lighting and natural ventilation. In this respect, the insulation and thermal characteristics of the building materials are important aspects to consider. It may be more expensive to use proper materials in the first place, but in the long run it would be much more effective and more economical.

The design of workplaces and workstations. Workplaces should be designed for the intended operators. If operators feel comfortable while performing their jobs, they are more productive and less likely to absent themselves from work. Workplaces and workstations designed according to ergonomic principles enhance workers' motivation, increasing their work capacity and productivity, and the quality of their work. It is more effective and cheaper in the long run to design ergonomically sound workplaces at the outset. Trying to correct workplaces later on is often more expensive and sometimes not possible.

Proper training of production and maintenance personnel. Effective production requires qualified personnel for the operation and maintenance of imported technology. The more

complex the technology, the greater the need for high quality personnel in sufficient numbers. In IDCs it is often necessary for firms to train their own personnel to meet the endemic shortage of qualified people. Proper training of operation and maintenance personnel should be conducted before establishment of the firm so that incoming technology will not be dependent on a foreign workforce. Maintenance issues are often neglected in IDCs and the technology is transferred without paying much attention to its maintenance. Machinery is often used as long as it operates and maintenance comes into focus only after a production stoppage. The concern for preventive maintenance and maintenance management is low in IDCs. As a result, output is mostly low due to many production stoppages. Further, lack of proper maintenance results in economic losses. It is common to encounter huge amounts of hardware which are nonfunctional.

Organization and administration. One of the major problems in IDCs with regard to industrialization is a lack of proper management. Although they import advanced technology, because technology utilization is usually low the economy suffers. One of the reasons for this problem is improper management and administration systems. Based on a systems perspective, if one of the major system components is changed, other components must be adjusted to this change in order to get the right system synergy and ensure high system output. For example, if new technology is introduced into the system, more should be done to change and adjust other factors of the system to be able to achieve a good-system output. This means that the organization as a whole must adapt to the new situation. In addition, human resources must be trained to use the new technology, and the needed information for producing high quantity and quality product must become available. Further, the environment must be redesigned for the new technology for safe and efficient operation (Figure 9.5).

In IDCs, the most common organizational structure is the traditional hierarchical system. In such systems, people usually passively await commands and instructions to do their work. As a result they do not use their creativity for proposing improvements or changes to the situation. But modern technology requires operator initiative and participation. Workers' participation and engagement will not only bring new resources and ideas to the company, but also increase employee motivation, resulting in higher quality

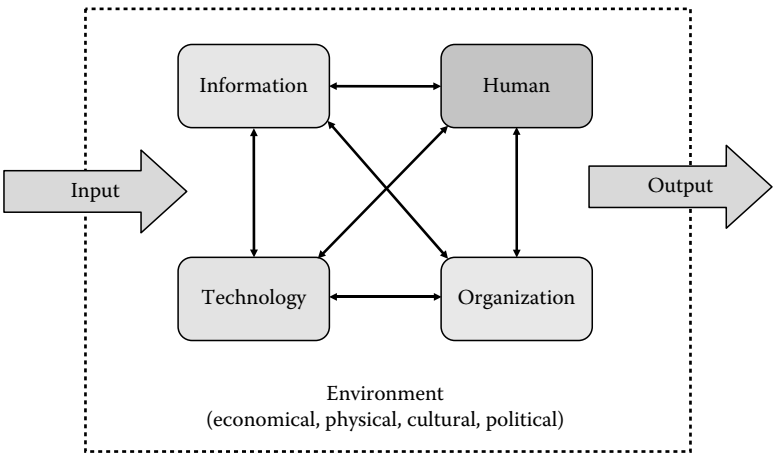

FIGURE 9.5
Components of a system.

and quantity output. The organization should consider these human aspects and assist employees to achieve their practical ends. It is said that a company cannot survive without the total involvement of its people. Involvement means participation in, and contribution to changes for improvement as well as having opportunities to influence decision making. High quality production starts with employees who have a thorough understanding of their job, know the risks involved in the operation, and have the confidence and motivation to participate in the company's day-to-day affairs as well as the authority to carry out the necessary changes for improvement.

Project planning and management. In many IDCs, projects usually costs much more and take much longer to finish than initially envisaged, mainly due to lack of proper planning. There are many examples of unsatisfactory technology transfer projects in which the project budget and time frame assigned for the project were not realistic. One helpful method for planning and managing projects is the Logical Framework Approach (LFA, 1999). By defining the goal, the purpose and the necessary activities as well as how and when to measure the activities and the needed resources on an LFA matrix, the stakeholders can monitor the project and, if needed, make adjustments. This method also helps to identify external factors which might influence the success of the project and enhance communication between the different parties involved.

9.5.5 Ergonomics Activities at Different Phases of Technology Transfer

It is not possible to recommend a general and detailed program or procedure for a technology transfer process which can be applied to all countries or enterprises due to the unique situation and characteristics of each country, the prevailing conditions within each country, and the nature of technology demand. Various technology transfer models which deal with this issue from different points of view are proposed in the literature. One of the models (which emphasizes "Human Factors" or ergonomics as an integral part of the transfer model and the need of technology modification to fit the local conditions of the recipient country) is that presented by Meshkati (1986). The proposed model emphasizes collaborative and mutually beneficial efforts of the two involved parties (i.e., supplier and recipient) for assuring a successful transfer process. Further, it emphasizes systematic integration of economic and ergonomics analyses in all five phases of the technology transfer process, involving both parties. The phases of the technology transfer process are shown in Figure 9.6. Joint action through coordination of both parties will help to obtain an outcome which is mutually beneficial (Shahnavaz, 1991). It is, of course, essential that both parties get regular feedback from each other in order to jointly decide the next design and development move.

9.5.5.1 Initiation Phase

The technology supplier's activities in this phase include: recognition of the receiver's needs and abilities to absorb, operate, and use the technology effectively. The technology supplier knows best the specific demands and requirements of the technology in question and can assess whether these requirements can be met by the technology receiver. Further, together with the technology receiver they can assess the needs for such technology and its usability in the new environment.

The recipient has the task of identification of relevant human factors and considerations affecting the intended technology, for example, collecting information about the impact of the intended technology on the workforce, the society, the environment, culture, and

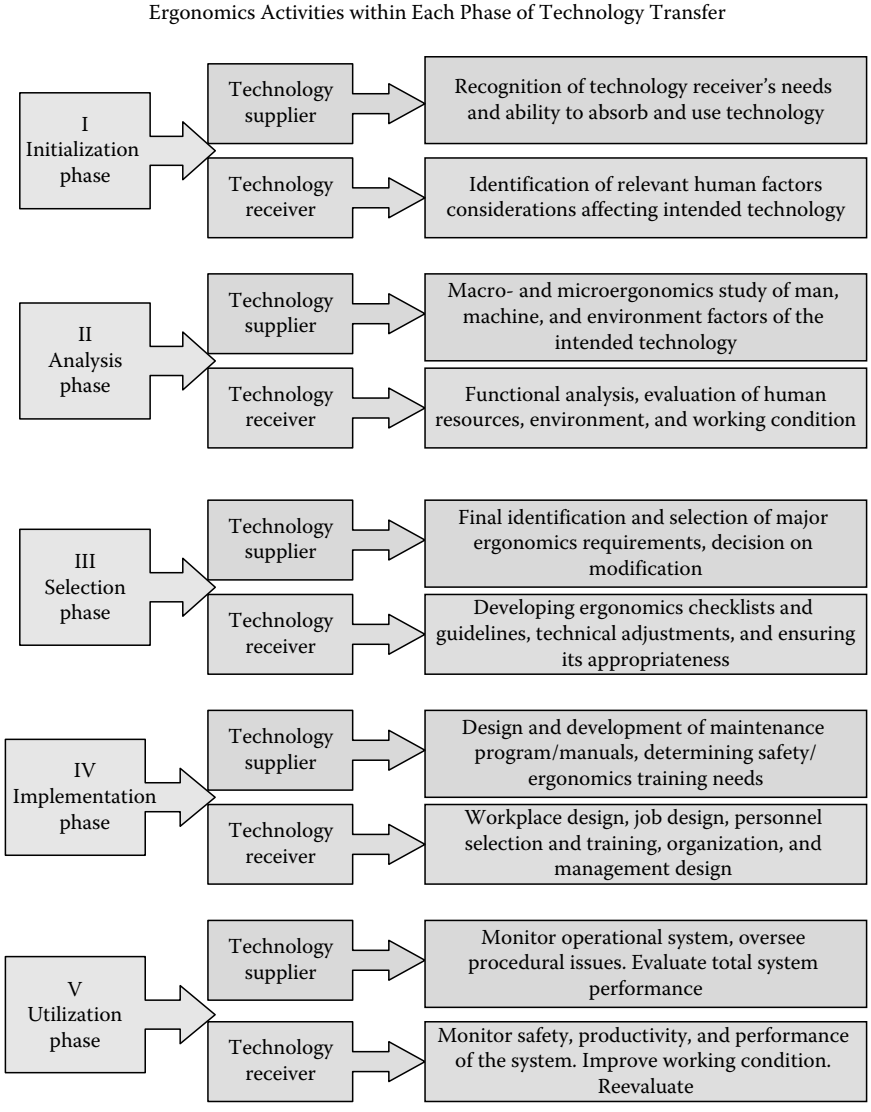

FIGURE 9.6
Phases of the technology transfer process.

quality of working life of the technology receivers. As the technology receivers know the overall conditions and the level of resource availability, it will be possible for them to present a realistic picture of the current situation and the future potential for making joint decisions about the usefulness (positive and negative effects) of the intended technology and its operational conditions in the new environment.

9.5.5.2 Analysis Phase

The supplier is responsible for macro- and microergonomics study of human–machine and environment factors relative to the intended technology. For example: What level of

knowledge and skills is required to use the technology efficiently? Are the needed human resource available or must people be trained? Is it possible to train people locally or should the technology supplier provide training? What infrastructure and facilities are available locally to meet the requirements of the technology? What kinds of modification are needed to fit the technology to the new environment? Due to the different climatic conditions in the recipient country, what type of technical modifications should be made for efficient operation? What will the effect be on the environment? Could the technology harm the environment? What are the risks involved? Are the local capacity, resources, and services adequate for dealing with eventual problems? What production systems are under consideration? What changes might occur within the current organization and management systems? Will these changes be acceptable? Is it possible to avoid the negative effects? Are there other alternatives? These and many other ergonomics, social, and cultural issues need to be considered by the technology supplier with regard to the technology in question.

The recipient needs to conduct functional analyses, evaluation of human resources, the environment, and the working conditions. The technology receiver should not completely depend on the supplier's analysis. Because the recipient is much more familiar with the local resources, requirements, and conditions, it is vital that a thorough analysis of the micro- and macroergonomics issues is made by the receiver. Focusing on its own needs, the recipient should assess what functions are required for the new production. Should, for example, automatic or semiautomatic machinery be used to meet the functional requirements? Which function should be allocated to machinery and which to human operators? Issues such as ensuring acceptable working conditions for employees, clean environments, human resource availability, and training needs are factors that also should be analyzed by the technology receiver. Further, the technology receiver must analyze the available absorptive capacity as well as the future potential, and make sure that the requirements of the intended technology will be met in the new environment within a safe margin.

9.5.5.3 Selection Phase

The supplier's analyses made in the previous phase provide a basis for further evaluations leading to the final decision of the technology to be selected for transfer to its new environment. The objective of this phase is to identify more specifically the ergonomics requirements and to determine the details of the technology to be modified. To avoid unnecessary major changes and waste of capital later on, further analysis may be needed in this phase before final selection is made. The technology suppliers must decide on modifications and adjustment, and find out which parts of the original design are not suitable for the new environment and how these should be improved. Do the operators in the recipient country have different morphologies and functional capacities compared to people the technology were designed for? To assess the degree of fit between the design and the operator, different methods can be used such as simulation studies or simply mock-ups. Mock-ups are a way of prototyping the user interface to acquire feedback from users about design and design ideas early in the design process. Three-dimensional mock-ups in cardboard or plastic can be used. Nowadays, computer simulation images can be used. They are much faster and more informative but more costly and require expertise which is usually available by the technology supplier. Further the most comfortable working conditions for the intended workforce should be defined. Do humidity and temperature levels exceed the original operational requirements for the technology? How can the technology be modified to suit the new environment and create comfortable operating conditions? Is there any environmental pollution (i.e., noise, dust, radiation, vibration, chemicals) involved in

the operation of the technology? If so, how can it be minimized? Are there any health and safety risks involved in operating and maintaining the technology? Do the hazardous parts have proper protective guards or accident prevention mechanisms? Can the operator understand the information presented by the technology and make correct interpretations? Can the operator use the controls comfortably? Will modifications create any new problems and cause danger to the operators? How can this be minimized and made safe?

The recipient firm should develop an ergonomics checklist to be able to assess the requirements of the intended technology in relation to its ergonomics criteria. This is to make sure that the demands of the intended technology are well within the operators' capacity. For example, it should be able to identify and provide information about the size and shape of the operators and make sure that the intended technology can be operated by the workforce without creating stress, trauma, and injuries. There are many ergonomics checklists available in the ergonomics literature. One of the most used checklists which were developed mainly for use in IDCs is the ILO *Ergonomic Checkpoints* (1996). The technology receiver should further clarify what functions are needed to be performed by the workforce, and check if the requirements can be met by the operators in terms of physical, mental, and knowledge demand levels. The receiver should develop ergonomics guidelines for safe and proper operation, maintenance, production, and material handling and make sure that the technology is accepted by the local workforce and the society in terms of its social and cultural impacts. Checklists provide good feedback information for the technology supplier to assist in modifying the intended technology. However, it should be said that sufficient ergonomics knowledge and skill to develop these checklists and guidelines are seldom available in the receiver firm. It is therefore necessary to seek assistance from (preferably local) consulting firms or universities who can help providing the required material. Also, it is the responsibility of the recipient government to collect and establish local demographic databases regarding national age and sex-based anthropometric profiles as well as national health, safety, and ergonomics standards. In this phase, through the joint action of both the technology receiver and supplier, the detailed ergonomics and engineering specifications are discussed and final decisions are made. Upon completion of this phase, the detailed transfer of technology becomes a reality.

9.5.5.4 Implementation Phase

The goal of this phase from the supplier's point of view is to make sure the transferred technology is working effectively in its new environment. The scope of this important task should include both micro- and macroergonomics. For example, hardware interfaces (both displays and controls) as well as operation and maintenance manuals should be tested by the actual users. Final identification and selection of major ergonomics requirements and decisions on modifications should be made. Modification of both hardware design and software needs to be made. The materials for special training required for operation and maintenance of the intended technology should be prepared. All safety guidelines and the original operational and maintenance procedures should be reviewed and tested with the actual users and any necessary modifications should be made. It is crucial that all information is available in the local language to avoid human errors attributable to a language barrier. Translation of the material into an understandable local language should be undertaken as a joint effort with the technology receiver.

The technology receiver should concentrate on workplace design; job design; personnel selection and training; organizational design; and the management systems. The workplace should fit the operators' functional and morphological capabilities and limitations.

All tools and equipment needed for any operation and used by the operators should suit them, be usable and should be located within reach. The operators should be able to work in comfortable and normal postures. Ergonomics checklists can provide information on these factors. Work environment factors such as lighting, humidity, temperature, ventilation, noise, and vibration should be designed according to ergonomics recommendations and tested with the checklist which was designed in the previous phase. Design of the building, placement of walls and windows, arrangements of machinery, and workflow are important issues to ensure good natural lighting and natural ventilation, as well as good and safe access and to minimize unnecessary material lifting and carrying. Further, job design is needed to ensure worker productivity, satisfaction, and safety. For each job, the job demand should be listed and operator selection and training should be conducted so that all operators are able to perform their assigned jobs without undergoing unacceptable problems. Each job demand should be within the operator's capability. The management system and information flow system must be designed considering local sociocultural conditions to ensure motivated employees and effective operations.

9.5.5.5 Utilization Phase

The supplier must consider the utilization phase at the end of a complete technology transfer process cycle, providing major feedback to ensure effective use of the technology and to achieve the expected goals of the technology transfer project. The objective of this phase is to monitor and evaluate the performance of the technology, providing useful feedback to both supplier and receiver as an input for improvement as well as for planning further projects. When the technology has been transferred and the system is running a trial production, both parties should work together in monitoring system performance in terms of quantity and quality of output as well as health, safety, and ergonomics issues. Through monitoring the hardware operational system, the software procedural issues, and the total system performance, it is possible to recognize problems in time and provide suggestions for improvement. Some factors to consider are: What are the most frequent errors made by the operator? Why do these errors occur? Can the errors be eliminated by improving the hardware, changing the work procedure, or both? Is there any problem with management procedures such as lack of information to the operator? Is the mental/physical load too high and thus causing errors to occur? Is the work-to-rest ratio appropriately designed with regard to work demand, climatic conditions, and the operator capacity? Does the shift system fit the operator's sociocultural lifestyle and family situation? In short, the technology supplier should monitor the operational system, oversee the procedural issues, and evaluate the total system performance in the trial production period.

The technology receiver should monitor safety, productivity, and performance of the system and try to reevaluate and improve working conditions. Even if the technology supplier has considered problems affecting the total system performance, the responsibility of the technology receiver cannot be avoided. In fact, the technology receiver is wholly responsible for health and safety of their employees and they should make sure that ergonomics interventions are implemented where necessary. For example, monitor whether any hazards are hidden behind the hardware design, especially in this new environment and with different users. Have safety guards been fitted in all hazardous places? Have all employees had proper safety training and are they working according to safety regulations? Do the operators fully understand the interface information, and the operational and maintenance procedures? The technology receiver should further evaluate total productivity in terms of quantity and quality, and assess if they meet the expectations.

If not, what are the problems? Are they hardware or software problems or human resource issues? What actions can be taken to improve the situation from micro- and macroergonomic view points to make improvement?

Transfer of technology is a very complex process and involves consideration of many factors. What we have discussed here is only related to ergonomics issues. Technology should also be assessed and modified from many other aspects of the whole, including economic, environmental, market share, profitability, and sustainability, all of which are beyond the scope of this material.

9.5.6 Assessing Appropriateness of the Transferred Technology

In order to minimize the problems related to industrialization and technology transfer in IDCs, it is of utmost importance for both the supplier and the receiver, or user, of the technology to consider the following questions and to try to find proper answers for them:

- Can the transferred technology (hardware and software) be safely, efficiently, and economically used in its new environment?
- Can the existing sociocultural and environmental conditions in the recipient country accommodate the imported technology?
- Is the technology beneficial to those who will be involved in, and affected by it?

Those responsible for the technology transfer and industrial development must accept their responsibilities and acquire the relevant knowledge in order to effect safe and productive industrialization and technology transfer decisions by:

- Considering human needs and limitations
- Considering environmental and sociocultural conditions
- Considering the infrastructure of the country and its absorptive capacity
- Considering the availability of both human and material resources for running, maintaining, and developing the transferred technology

Since many factors influencing the nature, extent, and diversity of the problems are specific to IDCs (such as climate, culture, methods of work, facilities, financial and human resources, management systems, level and type of industrialization), it is necessary for every country to conduct endemic research, and to provide education and training in these issues as an indispensable part of its development program.

9.5.7 Evaluation of the Transferred Technology

The first step in evaluating transferred technology is to determine whether it has been successful or not. In order to assess this, the output of the technology transferred must correspond with the initial expectations regarding quantity and quality. These expectations may come from an investor aiming for economic profit, or a larger enterprise hoping for profit and future development. In addition to financial success, there are also expectations from both the workforce (the technology users) and the general public in terms of their expectation of an improved quality of life, and these two must be taken into consideration. The success of the technology transfer is therefore determined by the accomplishment of

these expectations both in short and long terms. The following criteria should be taken into consideration when determining the level of success or failure of a technology transfer:

- Level of output (quantity and quality)
- Return on investment
- Production efficiency
- Safety and workers' health (low accident and injury rates)
- Satisfaction of employees and general public expectation
- Low rate of turnover and absenteeism

The potential of the technology transfer should be assessed using criteria such as:

- National and international competitiveness
- Market share
- User's acceptance
- Degree of customer reliance
- Potential for development

A successful outcome is very dependent upon the criteria on which the decision to select and purchase a particular technology was made, and on the overall capacity of the recipient firm to best absorb the technology.

9.6 Conclusion

The consequences of not considering ergonomics in the technological transfer process are numerous. One of the most common problems is the ensuing high rate of accidents and injuries. This not only causes human suffering, but with a large number of major accidents poor economies cannot sustain the exorbitant costs of consequent property damage. Another common problem is low productivity and low product quality of the transferred technology. This results from a mismatch between the transferred technology and its new operating environment and users. In general the most important factors contributing to unsuccessful technology transfer are:

- Low level of general education in the IDCs
- Week ability to identify factors of success and failure during planning and implementing
- Unrealistic results of market research and feasibility studies
- Financial constraints (shortage of foreign currency)
- Technical difficulties (appropriateness)
- Infrastructure (physical facilities)
- Communication and language problem between technology supplier and recipient

- Complex administration procedures in most IDCs
- Cumbersome legislation and problems of corruption
- Coordination (different standards)
- Export difficulties in the IDCs

All these factors are of significant importance. Technology transfer is the total sum of know-how and skills required to develop, manufacture, and distribute products under these circumstances. Fortunately, there is an emerging awareness and interest in occupational health, safety, and ergonomics issues in most IDCs. It is now mostly accepted that ergonomics is an essential means of assuring the efficient use of technology and the labor force. It is further becoming accepted that ergonomics can help to make best use of technology through optimizing the application of existing and transferred technology and by creating harmony between technology, organizations, humans, and the way they use information, all within a single environmental context.

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10

Ergonomics Issues in Transport

Dave H. O'Neill

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10.1 Introduction

The availability of appropriate transport systems, particularly the infrastructure, cannot be presumed as in place and effective in most industrially developing countries (IDCs). The nature of transport is such that for proper analysis or assessment purposes it must be considered as a system, or an interaction of subsystems, rather than as individual or discrete component parts. Furthermore, the characteristics of appropriate transport systems for IDCs may differ markedly from those in industrially advanced countries (IACs), the differences being even more pronounced between the richest and poorest countries. These differences will be briefly discussed later, but it is important to note that designs of transport systems successful in urbanized IACs are unlikely to be appropriate for predominantly rural IDCs.

Transport is a peculiar human activity—no other species demands or requires it. Even species that migrate, covering long distances on the hoof or on the wing, rely entirely on their own individual resources to achieve this. This would probably be better described as locomotion than transport, but many species have developed behavioral responses to organize themselves in certain ways to improve their survival prospects. It may be conjectured that when humans try to organize themselves to move people and goods, they do a poorer job than the members of the animal kingdom, but that could be attributed to the number of stakeholders with strong (and maybe conflicting) interests who rely on transport systems. Various political and sociological issues are implicated here, inevitable with so many issues affecting transport systems, and these are acknowledged (see, e.g., Beenhakker et al., 1987; Howe, 1990; Barwell and Dawson, 1993; Simon, 1996; World Bank, 1996; Malmberg-Calvo, 1997). However, for the purposes of this chapter, they are set aside

in order to focus on the ergonomics and human factors issues. The human effort expended on transport activities is huge and very often involves the use of very basic equipment as transport aids. Furthermore, these are often not well matched to the users' needs or characteristics, with likely adverse effects on their well-being. Despite this, very little attention has been paid to the ergonomics of transport, particularly rural transport where the majority of IDC populations gain their livelihoods.

There are many modes of transport with certain modes being favored for the movement of goods (which may be subdivided to bulk or smaller consignments), and others for the movement of people. Transport on water, for example, tends to be favored by the movers of larger consignments, particularly if speed is relatively unimportant, whether it is intercontinental across the oceans or, more nationally, through a network of inland waterways by barge on rivers or canals. People tend to travel by boat more for recreational purposes than for "getting from *A* to *B*." Air transport, on the other hand, is largely reserved for people who need to get from *A* to *B* as rapidly as possible. It may also be used for letters or small parcels delivered by airmail, even if these items may be collected together to form a bulk consignment. Some perishable materials with a short shelf-life (e.g., horticultural produce) may also be airfreighted, but this practice is being increasingly scrutinized because of the increasing concern over "carbon footprints." Road and rail transport are more versatile in that they may serve both purposes, but with lower limits on volume and speed. Furthermore, they do not need major investments in infrastructure such as harbors and airports. But neither railways nor roads are without their overheads, the former needing track to be laid and stations to be constructed, and the latter needing a reasonable road network for it to operate effectively and efficiently. Nevertheless in IDCs road transport is dominant, not only because it is associated with less overheads, but also because small trucks, cars, and motorcycles can often access very remote destinations or markets, despite the fact that the wear and tear which may result (due to poor or inappropriate terrain conditions) increases their operating costs. This would be the typical scenario for the 3 billion or so people who depend on subsistence agricultural production for their livelihoods in IDCs.

To put the road transport situation into perspective and illustrate a comparison between IDCs and IACs, Table 10.1 gives characteristics of road transport for selected countries. The differences between the IDC data and the IAC data are clearly evident. What is not evident in these data is the large number of kilometers of unclassified (without tarmacadam surface) roads and tracks which effectively constitute the "road" network in IDCs. But, despite the lack of formal roads, it has been questioned whether providing roads to connect the larger towns with rural areas is the most appropriate way to facilitate rural transport (see Barwell and Dawson, 1993; Connerley and Schroeder, 1996). Attempts to build expensive roads on limited budgets may be misguided when the best way to help the subsistence farmers (and their families) might be to enable them to move their goods (and themselves) more effectively on paths and tracks using bicycles, animal-drawn carts and human porterage, and even—in limited circumstances—head-loading. Although there are roads, which may receive reasonably regular maintenance (e.g., grading), thereby facilitating motorized transport between rural centers and larger markets, they have little relevance to the daily transport needs of most rural households. The case for improved road and track transport together with the necessary, but relatively modest, infrastructural demands is compelling for rural subsistence farming economies. The flexibility and versatility it offers for moving people and consignments of goods up to about 100 kg to and from remote or inaccessible places are unmatched by any other modes of transport. Although the World Bank (quoted by Estache, 1999) believes that "Governments should increasingly

TABLE 10.1

Vehicle Use in Selected Countries

Country	Total Vehicles	Vehicles/1000 Inhabitants	Vehicle/Kilometer of Road
Uganda	33,080	1.7	1.2
Ethiopia	66,021	1.2	2.3
Tanzania	133,800	4.6	1.5
Kenya	346,900	14	5.4
Zimbabwe	600,000	48.8	6.5
Egypt	1,703,300	28.3	29.2
India[a]	4,927,000	5.5	2.5
South Africa	5,450,000	137.1	30
Mexico	12,551,000	140.4	50.5
United Kingdom	23,077,000	406.2	42.9
Japan	67,245,000	538.3	58.8
United States	198,798,000	750.2	31.1

Source: International Road Federation, *World Road Statistics*, IRF, Geneva, 1997.

[a] Recent growth in the Indian economy likely to influence placing in the table.

be able to rely on the private sector for help supporting (and financing) the transport sector—especially infrastructure support services for which there is heavy demand …," this would clearly not be feasible in the subsistence farming sector.

10.2 Modes of Transport

Around 30 different modes of transport are available in rural, subsistence farming communities (see Table 10.2). These are fairly evenly divided between the human-powered, animal-powered, and engine-powered methods of goods or personal transportation. In selecting modes of transport, farmers take many different criteria into consideration. These include factors concerning the nature of the load (its size, weight, value, and distance to be transported), and then the availability of various types of transport, but above all, the main consideration is the capital cost. Consequently, the cheapest form of transport, human porterage (specifically head-loading by women) which requires no investment in equipment, thus further ensuring that the capital cost is minimal, is very attractive. Nonengine-powered modes are also attractive to subsistence farmers because there is no need to pay for (fossil) fuel, and with the economic value attributed to female labor being very low, methods of female human porterage would be expected to be prevalent. Ironically, however, when the costs of various modes of transport are analyzed in terms of cost-effectiveness or economic efficiency, the data from both Oram and Thomas (1995) and Crossley and Ellis (1997) show that head-loading and other forms of human porterage are the least efficient or economically effective. Data from Oram and Thomas, as presented in the review by Gebresenbet et al. (1997), are presented in Figure 10.1. As Figure 10.1 implies, head-loading is the least cost-effective but the attraction is that it requires no investment and, if head-loading is done by a member of the household (rather than hired),

TABLE 10.2

Possible Modes of Transport

	Mode	Human Transport	Goods Transport
1	Walking	X	
2	Back-loading		X
3	Head-loading		X
4	Shoulder yoke/pole		X
5	Wheelbarrow		X
6	Handcart—two wheels	X	X
7	Handcart—four wheels	X	X
8	Donkey[a]	X	X
9	Horse	X	X
10	Ox and sledge		X
11	Donkey and cart—two wheels	X	X
12	Donkey and cart—four wheels	X	X
13	Ox and cart—two wheels	X	X
14	Ox and cart—four wheels	X	X
15	Horse and cart—two wheels	X	X
16	Horse and cart—four wheels	X	X
17	Bicycle	X	X
18	Boda-boda (bicycle taxi)	X	
19	Bicycle with trailer	X	X
20	Motorcycle	X	X
21	Motorcycle with trailer/sidecar	X	X
22	Power tiller (i.e., two-wheel tractor)	X	
23	Power tiller with trailer	X	X
24	"Matatu" (commercial minibus)	X	X
25	Pickup (or car)	X	X
26	Bus	X	X
27	Lorry	X	X
28	Tractor (standard)	X	
29	Tractor with trailer	X	X
30	Boat[b] (rowed with oars)	X	X
31	Boat (engine-powered)	X	X
32	Boat (pulled from tow-path)		X

[a] Can add camel, buffalo, elephant, etc. as appropriate.
[b] Boats may include ferries, punts, barges, etc. (and may be with sails).

there is no cash payment. By definition, subsistence farming families are not members of the cash economy and have very little access to cash. Note that these scales are both logarithmic (rather than linear) so increasing the distance along the axes from the origin which represents very marked increases in the values of the parameters. In an alternative analysis, Figure 10.2 shows Sieber's (1999) analysis of transport costs according to distance and road quality (based on data from Crossley and Ellis, 1997). This also shows that head-loading is the least cost-effective, in terms of cost per unit of load and distance. The effect of poor road quality on the cost of any mode of transport is also clearly evident from Figure 10.2.

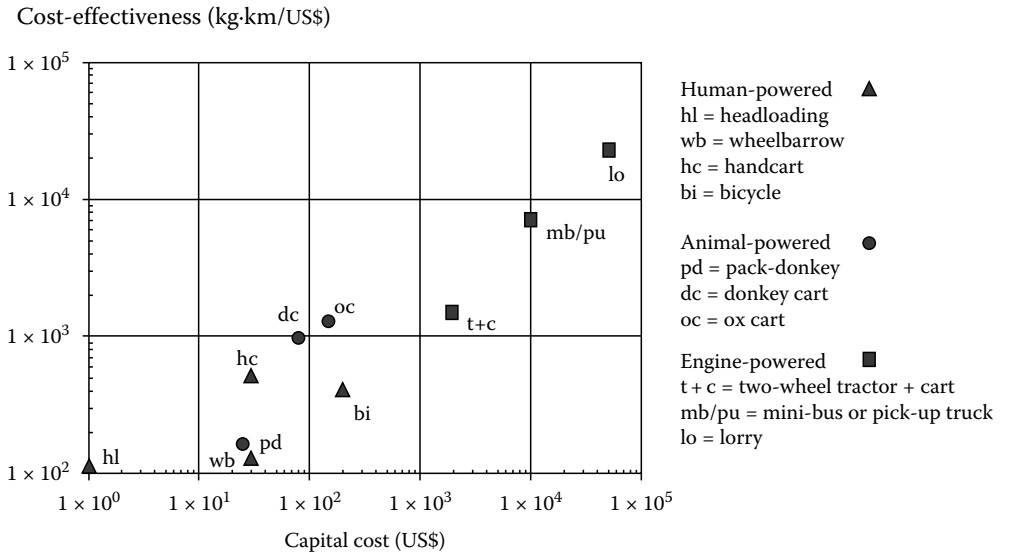

FIGURE 10.1
Cost-effectiveness versus capital cost of various transport modes. The modes represented by triangles (▲) or circles (●) may be generically referred to as NMT and all the modes except trucks are known as IMT. (From Gebresenbet, G., O'Neill, D.H., Mutua, J., and Oram, C., Technological support for rural agricultural transport and development. Paper to "East African Regional Workshop on Rural Transport and Development," Kenya Network for Draught Animal Technology, Nairobi, 1997; Oram, C.E. and Thomas, T.H., in *Small Engines, Their Fuels and the Environment*, Reading University, Reading.)

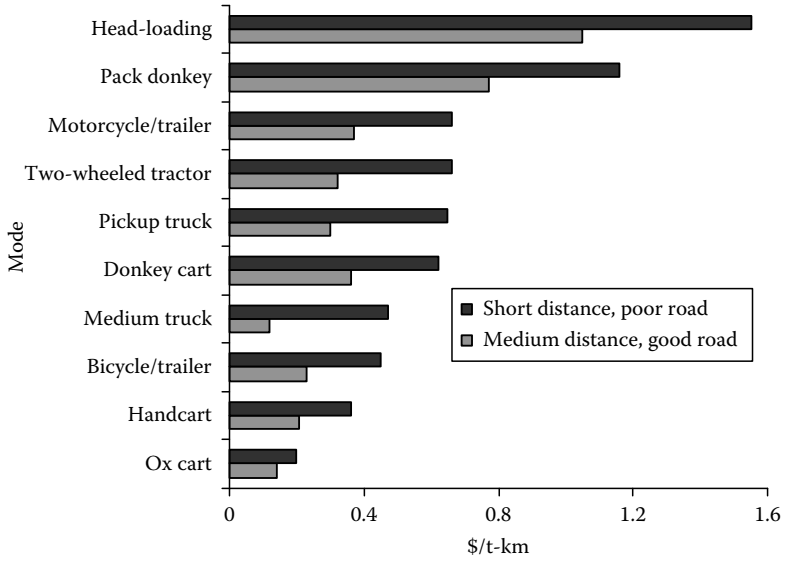

FIGURE 10.2
Cost of modes of transport under different conditions. (From Sieber, N., *Transport Rev.*, 19, 205, 1999.)

10.3 Typical Transport Needs in a Rural Community

In rural communities the main occupation is agriculture, either subsistence or small-scale commercial, and agricultural commodities provide the basis for most of the trading that is undertaken, which in turn generates much of the transport need. The well-being and livelihoods of all but the poorest subsistence farming families are heavily influenced by their ability to trade and, hence their need for transport for the marketing (selling) of their produce. Kleih et al. (2004), reporting on their studies in Uganda, stated that lack of means of transportation has been identified as one of the key constraints to farmers accessing marketing opportunities. A typical subsistence farming family has 1–2 ha of arable land in separate fields, or gardens, at varying distances from the homestead. The family needs with respect to transport are illustrated in Figure 10.3. The needs are based on moving agricultural inputs and outputs between fields, homestead, and market(s) plus domestic, educational, and social needs. The main agricultural needs are summarized in Table 10.3. Transport by human porterage is energetically demanding and requires a minimum state of physical capability and fitness. In the many communities in IDCs which have been badly affected by HIV/AIDS, this capability is seriously impaired. One of the main consequences of the loss of transport function is loss of marketing opportunities and hence, income. Generally speaking, motorized transport services in rural areas are not only limited but also inflexible in addressing the transport requirements of the rural population. Motorized transport is not a good solution here because the requirements are characterized by moving relatively small loads over relatively short distances, often off-road.

The domestic needs are mainly for the transport of water and firewood, often on a daily basis, and the transport of goods required at the homestead, bought at and brought from the market, usually once or twice weekly. For some families, particularly the poorest, the domestic transport burden is greater than that for agriculture because of the greater frequency of the needs and the relatively low crop yields that the poorest families

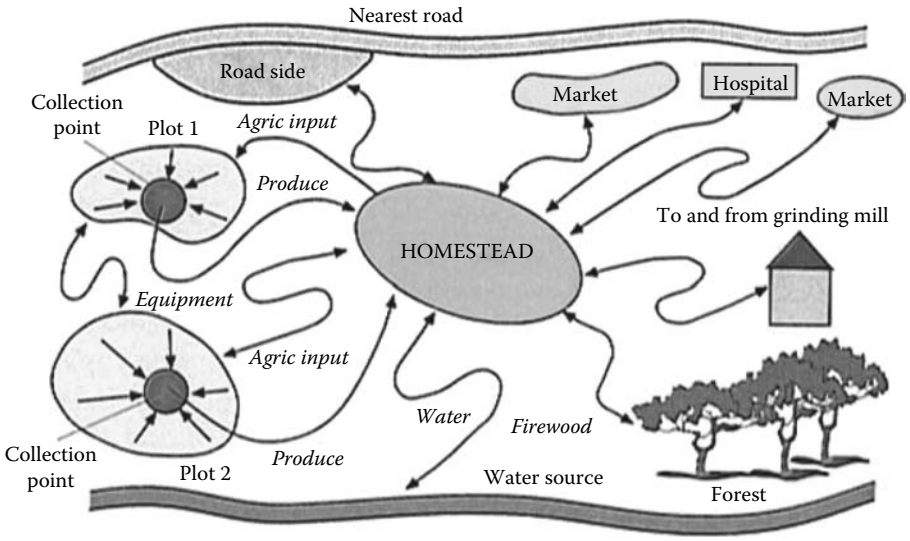

FIGURE 10.3
Transport characteristics of a typical smallholder farmer.

TABLE 10.3

Transport Demands of Crop Production

Nature of Load	Journey
Equipment (e.g., ploughs, cultivators, etc. where used)	From homesteads to fields and back[a]
Seeds and manure or inorganic fertilizer[b] (where used)	From homesteads to fields
Pesticides[b] (where used)	From homesteads to fields
Harvested produce	From fields to homesteads
Crop residues	For fodder (if appropriate), from homesteads to fields
Harvested produce	From homesteads to markets

[a] Typically, the poorest farmers have small fields (gardens), dispersed and, maybe, as much as 3 km from the homestead.

[b] Not for the poorest farmers.

often experience. For the poorest families, the use of regular animal- or engine-powered transport would rarely be affordable due to capital or hiring costs.

Some families may offer transport services as a means of earning income. These services range from members of the more wealthy families charging to carry goods on their animal-drawn carts to human porterage, usually provided by women from the poorer families. Human porterage is observed in a variety of forms (see Table 10.2) including, head-loading, back-loading, or a combination of the two, shoulder-loading (sometimes with yokes/poles), but rarely by hand with the arms hanging straight. Handcarts which are common in towns are rarely found in rural areas but wheelbarrows are used in some village communities. Bicycles can provide an attractive alternative to carts because they can carry a substantial payload (provided it is well balanced and secured) in one direction (see Figure 10.4) and then can be ridden in the other direction, significantly reducing the journey time.

FIGURE 10.4
Bicycle transport in Kenya.

FIGURE 10.5
Boda-boda park in Kenya.

In some areas of eastern Africa, young men provide an economical bicycle transport service (boda-boda), as shown in Figure 10.5, primarily for people but also for goods. The boda-boda may be regarded as a lower (capital) cost analog or alternative to the ubiquitous rickshaw of southern Asia (see Figure 10.6). Another major consequence of HIV/AIDS is the loss of income by the victims because they are no longer able to maintain the sustained physical effort required for porterage or boda-boda.

FIGURE 10.6
Rickshaws in Bangladesh.

10.4 Popular Means of Rural Transport

The most popular means of transport in rural subsistence communities are the nonmotorized transport (NMT) and the intermediate means of transport (IMT), as shown in Figure 10.1, because they are so much cheaper than engine-powered, four-wheeled (or more) vehicles. Figure 10.7 shows a schematic diagram of the types of NMT and IMT found in IDCs. The different modes are popular for different reasons, often depending on the circumstances where one mode may be more attractive than another. Considering the example of head-loading, Figure 10.8 illustrates a case where head-loading is being used almost certainly because it is the lowest cost option, although not necessarily the most effective. On the other hand, Figure 10.9 illustrates a situation where head-loading is probably the most practicable option. Typical human load-carrying abilities for healthy people, experienced in their particular mode, are shown in Table 10.4. Just as the "best" mode may depend on the circumstances, the optimum load (or maximum) for a person to carry cannot be prescribed as it depends on the person or the nature of the load. There are many possible determinants of load-carrying ability. These include body size, strength, age, nature of load, how load is supported, terrain, topography, climate, and clothing. Terrain, in particular, and its interaction with footwear can make locomotion difficult, and any additional

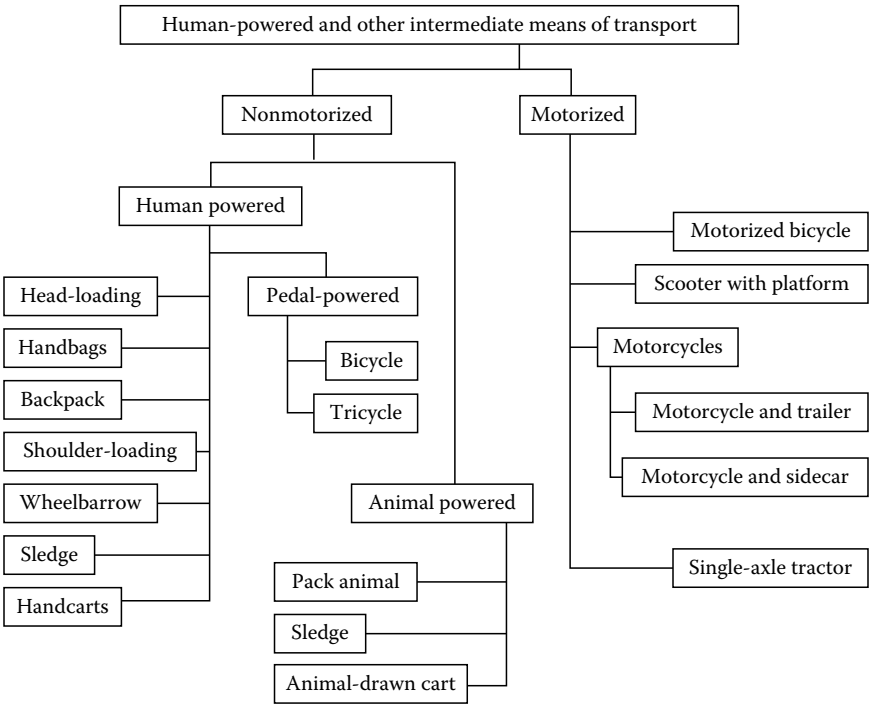

FIGURE 10.7
Components of human-powered and other IMT. (From Gebresenbet, G., O'Neill, D.H., Mutua, J., and Oram, C., Technological support for rural agricultural transport and development. Paper to "East African Regional Workshop on Rural Transport and Development," Kenya Network for Draught Animal Technology, Nairobi, 1997.)

FIGURE 10.8
Woman carrying firewood.

FIGURE 10.9
Woman carrying produce from field.

loading due to carrying can exacerbate this. Haisman (1988) has suggested that a useful "rule of thumb" would be to relate load-carrying capacity to body weight and that one-third of body weight would be an appropriate value for healthy young men. However, this is based on military data and extrapolating to subsistence farmers in IDCs would need validation. Reference to Figure 10.2 may suggest that bicycles and handcarts may be almost equivalent but, although the payload is less than that of a handcart, a bicycle can

TABLE 10.4

Typical Human Load-Carrying Performance Characteristics

Mode	Load (kg)	Speed (km/h)	Duration (h)
Head-loading	25	5	4
Back-loading	30	5	5
Shoulder-loading (with yokes/poles)	40	5	3
Wheelbarrow	50	5	2
Handcart	120	5	6
Bicycle	60	20	5
Tricycle	100	15	5

be used along the narrow (walking) paths, typical of so many rural communities, where it might be awkward to take a handcart. Also, a journey riding on a bicycle takes less than half the time for that of walking. Considering the close alternatives, animal carts (all varieties) need at least as much space as handcarts and, on the smaller side, wheelbarrows, despite the increased maneuverability over handcarts, generally carry less than bicycles and demand greater effort from the user.

While human porterage, with all its variants, is clearly one of the most feasible and popular modes of transport for the poorest families, it would be desirable to identify measures which could be taken to lessen the perceived burden and reduce the risk of injury. Carrying loads is associated with high rates of musculoskeletal injuries, especially to the back and the neck (e.g., deformation of the spine, slipped discs), resulting in aches, pains, and often reduced work capacity (see Curtis, 1994). Strains and sprains to limbs and joints can also occur, which may also be disabling, temporarily or permanently. Various possible practical interventions, which demand the application of ergonomics, include:

- The design of carrying aids (e.g., back-mounted baskets, shoulder poles, or yokes)
- The design of basic vehicles (e.g., handcarts and wheelbarrows)
- Bicycle-mounted devices (e.g., racks, panniers, and trailers)

To complement the data given in Table 10.4, Table 10.5 shows the performance of IMTs. Note that Table 10.5 gives maximum values for the parameters selected whereas Table 10.4 gives sustainable levels attainable by fit, healthy, experienced people.

10.5 Other Physical and Ergonomics Considerations

Physiological interest in load carriage has a long history, which even precedes the introduction of the word "ergonomics." Much of it was due to military interest and dates back to the days when the infantry could have a significant influence on the outcome of battles, especially for territory. Cathcart et al. (1923) suggested that for (British) soldiers, marching at a speed of about 5.6 km/h (about 3.5 mph), the most economical load would be around 40% of body weight. Legg (1985), also investigating military applications, stated

TABLE 10.5

Performance of IMT

Modes	Max. Load (kg)	Max. Speed (km/h)	Max. Range[a] (km)	Topography Required
Wheelbarrow	100	5	10	Flat narrow path
Bicycle	75	20	20	Flat narrow path
Bicycle + trailer	200	10–15	15–20	Flat wide track
Pack animals	100–250	5	15–20	Narrow path, can be hilly
Animal-drawn sledge	200–400	5	10	Flat
Animal-drawn cart	500–1500	5	15–20	Flat wide track
Scooter with front platform	150	50	60	Motorable path
Scooter with rear platform	500	50	60	Motorable path
Motorcycle	100	40–90	100	Motorable path
Motorcycle + sidecar	250–300	30–60	60	Flat wide motorable track
Motorcycle + trailer	250	30–60	60	Flat wide motorable track
Single-axle tractor + trailer	1500	15–20	40	Flat
Asian utility vehicle	1000	60	60	Motorable track

Sources: Adapted from Riverson, J. and Carapetis, S., Intermediate means of transport in sub-Saharan Africa. Its potential for improving rural travel and transport. World Bank Technical Paper No. 161, The World Bank, Washington, DC, 1991; Crossley, P. and Ellis, S., *A Handbook of Rural Transport Vehicles in Developing Countries*, Crowthorne, Berks, TRL Ltd., 1997.

[a] For motor vehicles, assumes fuel available.

that a double pack system was the most efficient, supporting Winsmann and Goldman's (1976) findings that it was important for the load to be well distributed over the body. Datta et al. (1975) stated that the maximum permissible load should not exceed 56% of body weight. They added that the maximum head load for an Indian male on firm terrain should be 30 kg. Bedale (1924) studied eight modes of load carriage, with loads ranging from 9 to 27 kg and found the yoke to be the most efficient. His efficiency parameter was milliliter of oxygen consumption per unit of work output, measured as the product of load and (horizontal) distance moved. He found head-loading to be less efficient and hip-loading the least efficient. More recently, however, Balogun et al. (1986) preferred a head pack to either a transverse or frontal yoke. His subjects were American college students. Kram (1991) investigated the use of springy poles as yokes and found that they had little effect on metabolic costs. Assessments of the metabolic cost of head-loading have produced some interesting results. It would seem that for experienced head-loaders about 20% of body weight can be carried on the level without incurring a metabolic cost but, thereafter, oxygen uptake increases (e.g., see Maloiy et al., 1986; Charteris et al., 1989). However, the absence of metabolic cost does not mean that there is no cost at all. Head-loading is associated with high rates of musculoskeletal injuries, especially to the back and the neck as discussed above (Curtis, 1994). Head-loading may be subdivided according to how the load is carried. It may be carried above the top of the head (as illustrated in Figures 10.5 and 10.6) or the load may be supported using a strap around the forehead, as illustrated in Figure 10.10. The former is probably the more common but the latter is favored in some communities. The study of Maloiy et al. (1986) included both loading methods and the metabolic costs observed for each method were not significantly different.

FIGURE 10.10
Woman head-loading using a forehead strap.

10.6 Road Transport

In most IDCs, rural populations still outnumber urban populations and, for most rural families and communities, transport (either personal or goods) means travelling on paths and tracks, and on roads only occasionally. Nevertheless, the road system/infrastructure is still essential to the well-being of these communities. It connects them with major commercial centers which are important for marketing their produce and should facilitate their travelling significant distances from their own communities in order to conduct whatever business or social interactions they have to undertake. There are very few rural dwellers in IDCs who would travel by rail or air (or even boat, except where a ferry crossing may greatly reduce their journey). It is worth considering, therefore, the nature of road networks in IDCs and the characteristics of using them. Road networks exist to permit, if not facilitate, the movement of road vehicles with their payloads of passengers and goods between two or more points. These are often convenient for other modes of transport such as animals or animal-drawn carts to use them. It may be debatable whether bicycles should be described as road vehicles, considering how and where they are used. And when a road offers a good route between two busy places, it will be used by pedestrians. The existence of these other users may not be fully acknowledged by road designers and this has safety implications for the users. Road use in IDCs is, therefore, relatively risky compared to road use in IACs, and there are likely to be more injuries and fatalities per road user in IDCs. The safety of the road network (system) depends on the drivers (their skills, cognitive processing, and state of arousal), condition of the vehicle and, to some extent, the state of the roads. These factors are beyond the scope of this chapter but must not be overlooked. Many of those who live in IDCs use the road network by hitching lifts on lorries or pickup trucks, or by buying a fare to travel by bus. Both of these are associated with danger

FIGURE 10.11
Road accident (Bangladesh).

because of (1) driver skills being eclipsed by impatience or fatigue, and (2) the poor condition of the vehicles, which may frequently be described as not roadworthy in IACs. Dreadful accidents with multiple fatalities (not only the vehicle occupants) are a frequent occurrence. A typical example is given in Figure 10.11. These are not ergonomics issues directly, but should not be overlooked when considering the road network holistically.

Urban road transport is somewhat different from rural transport in IDCs. Most towns and cities are densely populated and the roads rarely seem to have the capacity to accommodate all the users. There is a much higher passenger transport requirement in urban areas which is largely met by minibus services run by private operators. Municipal bus services or railway networks (in the larger cities) cannot hope to meet the needs of the very densely populated shanty towns. The private minibus owners tend to own fleets of vehicles and offer franchises to drivers to run on specified routes. These drivers pay considerable sums of money for these rights plus use of the vehicle and have to recover their investments by collecting as many fares as possible. This means carrying as many passengers and making as many journeys as possible every day. Consequently, the minibuses are usually (1) overloaded, (2) driven too fast, and (3) poorly maintained, if at all, as there is no incentive (legal or moral). Simply put, they are dangerous—but all significant stakeholders seem content with, or at least tolerant of, the situation. As well as minibuses, the main road users are pickup trucks, cars, lorries, bicycles, mopeds/scooters (or other two- or three-wheeled motorized vehicles) and pedestrians (with or without handcarts). In some regions there may be significant numbers of animal-drawn carts, but these may well be substitutes for pickup trucks and mopeds/scooters. All these users are vying for inadequate road space, thereby increasing congestion and danger, but maybe the beneficial effect of congestion is the slowing down of the minibuses.

This scenario does not present many options for ergonomics interventions. The traditional ergonomics approaches to improving transport include (1) reduction of driver error, (2) vehicle design, (3) effective maintenance regimes, and (4) system safety. For urban transport in IDCs, driver error is influenced mainly by the speed at which the driver feels

compelled to travel and, in fact, observations suggest that many drivers are quite skilled and have a better idea of the size of their vehicles (and the size of gap they can fit into) than their IAC counterparts. Most vehicles are imported and so are designed primarily for different transport circumstances and target populations. There is no incentive to carry out any maintenance beyond keeping the vehicle "on the road" so that it can continue to provide a return (economic). System safety can be affected by the design of the road network and, perhaps more importantly, the attitudes of the users, but influencing either of these would be major undertakings.

10.7 Concluding Remarks

This chapter has focused on road (and track) transport in rural areas. There are two reasons for this: (1) many ergonomics issues present themselves and (2) the livelihoods of around 3 billion people are affected. For subsistence and smallholder farmers who want to develop or expand their enterprises, transport is essential. Without an accessible transport infrastructure, there are limited marketing opportunities and only minimal scope for expansion. In many, if not most IDCs, however, transport development strategies are aimed at the promotion of manufacturing industry or commercial farming. Small-scale farmers and their needs are ignored and, thus, remain isolated and poor. According to Gleave (1992), who believes that two transport networks (indigenous and modern, as they are termed) can coexist, small-scale farmers cannot really access the modern networks because the nature of their activities makes modern networks unaffordable and so they rely almost exclusively on their indigenous ones. The "transport gap" which exists between human porterage and pickup trucks could be met by greater development and use of IMTs. Although many of these are currently unaffordable to small-hold farming families, it is felt that improved designs, in terms of both low-cost manufacture and better user interfaces, the wider availability through the economy of large production runs could alleviate many transport constraints. A similar argument could be applied to animal-drawn equipment too. The lack of cost-effective means of transport in IDCs (see Figure 10.1) is a reflection of the level of poverty. This is not going to change quickly so the development of IMTs—an appropriate technology—may be an appropriate solution or approach to follow. However, quoting from Jafry (2001):

- There is no easy answer to the transport problems of the poor—most people cannot afford transport.
- The poor may be helped by reducing transport burdens—by either the development and provision of carrying aids or the transfer of part of the burden to modes other than human porterage.
- Carrying aids should be developed within the target communities taking account of gender and cultural factors as well as the physical factors.

In the literature, the wider use of IMTs has general appeal for the economists because the investment is relatively low and the return is relatively high (see Figure 10.1). The relative attractiveness of NMTs, within this category, is now increasing because of the escalating cost of fossil fuel. The increased availability and use of IMTs (using animal

power or even small, economical engines) would provide a realistic option for small-scale farmers to improve their marketing and hence, their livelihoods. For ergonomists, such a scenario would represent a significant challenge because all IMTs depend heavily on human effort or human control (or often, both). However, it is a challenge that can be adequately addressed with current knowledge of work and thermal physiology, biomechanics, interface design and work organization, provided that this knowledge be applied in (or adapted to) the correct cultural context. Therefore, the collaboration of ergonomists, socioeconomists, and design engineers now provides an unprecedented opportunity to lift millions of small-scale farming families out of poverty into the market economy, where their skills are likely to be better rewarded and their livelihoods improved. A further benefit would be enhanced food production/availability, which, midway through 2008 alongside rising fuel costs, is becoming an issue of global concern. Such a promising opportunity should be heeded by our politicians.

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11

Distinctive Ergonomics Requirements of Developing Regions: Economic Costs and Benefits

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11.1 Background to the Problem

The cost of occupational health and safety problems remains substantial in both developed and developing countries. For example, according to the Department of Labor in the United States (United States Department of Labour, 2007a and b), there were 5703 fatalities and 1.2 million cases of injury or illness requiring time off work (with a median number of days away of seven) in 2006, while the Health and Safety Executive (HSE) (2007) indicates that there were 241 fatalities and in excess of 400,000 cases of injury at work (accounting for a total of 36 million working days lost) in Britain. Even in smaller economies such as New Zealand, the costs are significant, with a total of 235,200 occupational injuries costing in excess of 225 million New Zealand Dollars being shown for 2006 (Statistics New Zealand, 2007). Unfortunately such statistics are significantly harder to come by in developing countries. For example in 2008, the International Labor Organisation (2008) only reports on occupational injuries for India in the mining and quarrying sector (38 fatalities

and 162 nonfatal injuries per 100,000 workers). According to the South African Department of Labor (2007), a total of 2070 million South African Rands (approximately equivalent to 258.75 million U.S. dollars) was spent on 886,511 workers' compensation claims.

In 1987, Shahnavaz described the economic cycle of diseases that plagues economic development in industrially developing countries (IDCs) (Shahnavaz 1987), and 13 years later O'Neill (2000) used the same terminology in discussing the application of ergonomics in IDCs, suggesting that over this time little had changed to improve economic conditions in most IDCs. The combination of poor working conditions and the exploitation of workers which is characteristic of developing countries is a key factor impacting negatively on productivity in these countries. Considering that approximately three quarters of the world's population lives in these developing regions, this constitutes a significant hindrance to the economic and therefore social development of the world.

A resource which can be used to alleviate poor working conditions is the introduction of sound ergonomics principles. According to the International Ergonomics Association (2000), the goal of ergonomics is the optimization of the human–machine interface through the evaluation of tasks, jobs, products, environments, and systems in order to make them compatible with the needs, abilities, and limitations of people. As such, it could be expected that the implementation of ergonomics in any working environment will have a profoundly positive impact. In 1996, in his presidential address for the Human Factors and Ergonomics Society (HFES), Hal Hendrick went so far as to state:

> Indeed, through the application of our unique human–system interface technology, we have the potential to truly make a difference in the quality of life for virtually all peoples on this globe. In fact, I know of no profession where so small a group of professionals has such tremendous potential for truly making a difference.

Furthermore Ozbayrak et al. (2004) assert that on a global-scale companies are being forced to produce high quality products at a reasonable cost by increasing competitiveness. For companies to achieve this, they are required to become more flexible, integrated, and automated. As such, one could expect that with the unique insight possessed by ergonomists, all companies worldwide would be approaching them in an attempt to optimize production and thereby increase financial competency. It is therefore surprising that more than 10 years after Hendrick identified the ergonomists' potential, they are still struggling to establish themselves in IACs and IDCs. Both Hendrick (1996) and Helander (1999) have sighted reasons for the failure of ergonomists to have the expected impact on the industrial world. These factors include exposure to bad (or "voodoo" as coined by Chong in 1996) ergonomics, the belief that ergonomics is only common sense, that ergonomics should be implemented because it is the right/moral thing to do, and that laboratory and field experiments take too long, among others.

However, there are numerous authors (e.g., Hendrick, 2003; Beevis and Slade, 2003; Stanton and Baber, 2003) who argue that the single most important obstacle to the growth of ergonomics is the failure of ergonomists to effectively demonstrate the financial benefits that can be gained from an ergonomic intervention. Stanton and Young (2003) argue that even with the propagation of ergonomics methods in the areas of research, teaching and even industrial practice, "there is little substantive empirical evidence that these methods actually work." Beevis and Slade (2003) suggest that this stems from the historical background of ergonomics being based on the improvement of performance of existing "man–machine" combinations rather than improvements in the efficiency measured in terms of value added per human hour. These authors further suggest that factors such as company security have also reduced the number of reports on the benefits of ergonomics.

As recently as 2003, Beevis and Slade argued that there is a paucity of data available on the financial benefits of ergonomics, and as such, the profession is ill-equipped to refute allegations that there are no financial benefits from an ergonomics program. It is no longer sufficient for ergonomists to use moralistic arguments to persuade management to take health and safety issues seriously. Increasingly, management's primary concern is the "bottom-line," and as such it is now necessary for ergonomists to demonstrate the linguistic nuance of accountants and finance managers in their motivation for the implementation of ergonomics. Oxenburgh and Marlow (2006) contend that ergonomists have the responsibility to "use all reasonable means to get their ideas accepted and implemented." One of the best methods which is available is to demonstrate the financial benefits that can be gained from workplace improvements. Zink (see Chapter 2) argues that it is important to "sell" ergonomics in IDCs. Stanton and Baber (2003), in their editorial for the special edition of the journal *Applied Ergonomics* on cost-effectiveness of ergonomics, stress that "we need to be able to present a strong business-case first, and then underpin this with an appeal to broader issues with which ergonomics is more familiar."

Therefore an understanding of the economic costs and benefits associated with the implementation of ergonomics programs becomes a key factor in convincing managers in developing regions of the efficacy of ergonomics. Most importantly, it allows the ergonomist to effectively demonstrate the financial benefits that can be gained through the introduction of sound ergonomics principles. This chapter therefore first focuses on the key determinants of the costs associated with ergonomics interventions, and then on the financial benefits that can be gained from the effective implementation of ergonomic principles. Lastly, the chapter will address some of the problems specific to IDCs hindering the calculation of the costs and benefits of ergonomics programs.

11.2 Determining the Costs and Benefits of an Ergonomics Intervention

Although the costs of ergonomics interventions are relatively easy to identify, the benefits are not always so clear (MacKinnon and Scott, 1998; Hendrick, 2003), and Beevis and Slade (2003) point out that determining the financial impact of reductions in accidents and injuries can be complex to calculate. This is made more difficult by the fact that ergonomic interventions are often part of some larger project aimed at upgrading the production process. Abrahamsson (2000) and Beevis and Slade (2003) contend that another problem associated with determining the benefits of any ergonomics intervention is that such benefits are not always possible to value in monetary terms while others have uncertain relationships with the actual interventions. Beevis and Slade (2003) use the example of employing ergonomics data to design a chair where all that can be argued is that because the chair is better than it might have been, consequently the sales should be better. However, this is a qualitative advantage rather than being quantitative. Consequently, Abrahamsson (2000) identified four different categories of economic effects as illustrated in Figure 11.1. There are several models (Hendrick, 1996; Boff and Rouse, 1997; Sharit et al., 2004; Lahiri et al., 2005; Oxenburgh and Marlow, 2006) that have been proposed to determine the costs and benefits of ergonomics interventions. However, perhaps, the best known of these models was presented by Hendrick (1996) and again in 2003, and as such it will be the focus of this chapter.

	Direct relation to ergonomic intervention	Relation to ergonomic intervention uncertain
Direct value in monetary terms		
Value in monetary terms uncertain		

FIGURE 11.1
Relationship between financial gains and ergonomic interventions. (Adapted from Abrahamsson, L., *Appl. Ergon.*, 31, 1, 2000.)

11.2.1 Measuring the Costs of Ergonomics Interventions

The factors which need to be taken into consideration in determining costs are relatively few in number and the data required are usually readily available making this calculation comparatively simple. There are four key cost areas which need consideration:

- Personnel costs
- Equipment and materials
- Reduced productivity and/or sales
- Overhead costs

11.2.1.1 Personnel Costs

There are three cost generators within personnel. First, the costs associated with hiring an ergonomics consultant which can be easily determined from the contract proposal provided by the consultant. Problems that may arise in determining these costs when the internal personnel responsible for providing the consultant with their brief have provided information that is not sufficiently complete for the ergonomists to provide an accurate response. This concern is of particular pertinence in IDCs where many of the individuals sourcing help from ergonomists may not fully appreciate the extent of the workplace problems or the changes that will be required.

Second, it is necessary to consider the time spent on the project by internal staff members. To calculate this accurately, it is necessary to take their salary, benefits, and overhead calculated prorated according to the number of hours spent on the project. It is therefore the responsibility of the individual in charge of determining the cost to identify the individuals who will be required and to determine the number of hours they will have to spend on the project. Typically, even in IDCs, salary and benefits information can be obtained from either the accounting or human resources departments (MacKinnon and Scott, 1998).

Third, modifications to the work environment often require employee downtime when they are unable to perform their normal tasks, and this needs to be considered in the costs of the project. This downtime must only be included if it can be clearly demonstrated that it is an additional cost, as under many circumstances, the ergonomics intervention is part of a larger project and the downtime would have occurred anyway, or the employees are used in another area of the factory or the downtime is used for training. Under these circumstances, the downtime should not be included in the calculation of the cost. When intervention programs are effectively planned, the amount of employee downtime can be kept to a minimum.

11.2.1.2 Equipment and Materials Costs

For most projects, the equipment or materials used will be directly purchased and hence the purchase price can be used as the direct costs for the ergonomics intervention. Lahiri et al. (2005) stress that this should include only the direct additional costs, or what economists term the marginal cost. They use the example of purchasing ergonomically approved adjustable chairs as an intervention to reduce the prevalence of lower back pain. Only the cost of the ergonomically approved chair over and above the price of the traditional chair should be considered as equipment cost. Under some circumstances (although it only occurs irregularly), the intervention may result in an increase in the maintenance costs of equipment. Under these circumstances, the added costs also need to be taken into consideration.

11.2.1.3 Reduced Productivity and/or Sales

Due to stoppages along the production line, interventions may hamper production or sales for a period of time. Obviously the lost revenue during this period also needs to be included. However, when projects are planned well in advance, such problems can be avoided.

11.2.1.4 Overheads

Overhead costs such as advertising, depreciation, and general administration are usually administered by the company's accounting department. Hendrick (1996) argues that some ergonomics interventions are highly likely to reduce the overall overheads and this reduction needs to be taken into consideration.

11.2.2 Determining the Benefits

There are three general classifications for economic benefits associated with ergonomics interventions:

- Personnel benefits
- Materials and equipment benefits
- Increased sales (through product design projects)

11.2.2.1 Personnel Benefits

The implementation of sound ergonomics principles within industry can significantly improve the productivity of the personnel working in the upgraded areas, including increased output per worker, as well as reductions in error rate, accidents, injuries, and illness, training time, skill requirements, maintenance time, absenteeism, and worker turnover.

11.2.2.1.1 Increased Output per Worker

Many ergonomics interventions result in a greater output per worker relating to improvements in workstation design, equipment redesign, software redesign, and macroergonomics intervention. Although in advanced countries this information may be readily available to the ergonomist, making the calculation of the benefits gained simple, the data

required may be less accessible in developing countries. It might therefore be necessary for the ergonomist in IDCs to ascertain the appropriate worker output statistics before and after the intervention themselves. Although this may be time consuming, it is essential in demonstrating the benefits of ergonomics. Detailed examples of how each of these can be demonstrated can be found in an article by Hendrick (1996) that can be downloaded free of charge in PDF format from the Human Factors and Ergonomics society Web site (www.hfes.org).

11.2.2.1.2 Reduced Error Rate

Reduction in the error rate of employees is a quantifiable performance benefit. It must be noted that the correcting of errors tends to take time, therefore the improvements in productivity may not be immediately apparent. Furthermore reductions in errors have been shown to result in a reduction in accidents, equipment damage, personnel injuries, and the related costs (Beevis and Slade, 2003; Hendrick, 2003). It is possible for the ergonomist in IDCs to perform a pre- versus post-intervention analysis of the employee error rate to quantify the impact of the ergonomics intervention.

11.2.2.1.3 Reduced Accidents, Injuries, and Illness

Most ergonomics interventions will strive for reductions in the number of accidents, injuries, and illness through the matching of the human operator and the machine. Beevis and Slade (2003) use the example of the provision of prescription safety glasses to the 35%–40% of workers requiring them, and plain safety glasses to the rest, costing less than the projected cost for workmen's compensation for a single eye injury. This is most commonly calculated by taking the reduction in the time lost from accidents, injuries, and illness multiplied by the labor cost per unit of time. Mathematically, this can be described as follows:

$$\text{Annual value of increase in productivity due to the intervention} = \text{number of workers subject to intervention} \times \text{number of work hours per week} \times \text{number of weeks worked per year} \times \text{coefficient of productivity gain due to the intervention}$$

where coefficient of productivity gain = adjusted average wage-rate taking into account the percentage gain in productivity – average wage-rate.

11.2.2.1.4 Reduced Training Time

There are several reasons why training time could be reduced through ergonomics interventions including functions and processes which are easier to perform and require less time to learn. According to Hendrick (2003), there are several other reasons for the reductions:

- Reduced turnover of employees
- Reduced time loss from accidents and injuries
- Reduced absenteeism
- Fewer people required to perform a given function

The savings in training time can be converted to saving in the cost of training and these used to derive the direct economic benefit. Hendrick (1996) contends that not only can

ergonomics be used to reduce training time, but also to make the training programs themselves more effective.

11.2.2.1.5 Reduced Skill Requirement

It is argued by Hendrick (2003) that improvements in the design of a job can have important implications for companies as they reduce the skill requirements for particular jobs. As such individuals with lower skill levels, and therefore paid lower salaries, can be used in the specific job, and the resultant salary savings considered as an economic benefit. This can be of particular relevance in developing countries, which are often characterized by a shortage of skilled workers, thereby offering employment opportunities to the larger less skilled portion of the population.

11.2.2.1.6 Reduced Maintenance Time

Macroergonomics projects incorporating improvements to equipment and/or work systems may reduce the maintenance costs; hence the number of personnel required can also be reduced. Once again the direct savings in salaries and benefits can be used to determine the economic benefit.

11.2.2.1.7 Reduced Absenteeism and Turnover

Not only can ergonomics interventions reduce worker absenteeism through a reduction in accidents, injuries, and illness, but also through the creation of a more suitable working ambience. Furthermore, Hendrick (2003) contends that reduced absenteeism also promotes productivity due to fewer disruptions to the workflow and less work being performed by the often less skilled and less experienced replacement workers. Not only do macroergonomics projects reduce absenteeism, but the associated improvement in quality of life may result in a reduction in the turnover rate of employees which can be a significant financial benefit. Beevis and Slade (2003), using an example demonstrating the impact of reductions in noise exposure in an office environment, found decreases of 37% and 47% for sick leave and staff turnover, respectively, both of which are significant factors in determining productivity. Most companies even in developing countries keep records of absenteeism and worker turnover, thus calculating the associated benefit is straightforward.

11.2.2.2 Productivity Benefits

Hendrick (2003) identifies several key areas where significant savings can be made relating to improvements in productivity. First, effective ergonomics design can have a significant impact on the amount of scrap produced by reduction of the number of errors made and improved product inspection techniques. Hendrick (2003) maintains that the benefits can be calculated directly from cost accounting data shown on a per annum basis. The introduction of sound ergonomics principles often results in products being produced using fewer and/or less expensive materials. These savings can be calculated using the purchase price of the materials being used. Similar improvements are seen in the reduction in maintenance requirements, where the number of tools and the amount of materials required are reduced, and where the purchase price can be used as the economic benefit. Lastly, due to reductions in errors being made by operators, equipment damage is less. Beevis and Slade (2003) list several examples of ergonomics projects focused on the effective redesign of equipment and the financial benefits that can be gained from these projects.

11.2.2.3 Less Tangible Benefits

There are also less concrete benefits, including:

- Life-cycle costs savings
- Demonstrating a genuine concern for the employee by management
- Fostering greater employee commitment, loyalty, and good citizenship behavior
- Improved corporate image resulting in less government scrutiny and better community relations

There are several benefits, not as easy to value in a monetary sense, which are nonetheless important. Some of these benefits are related to the design of products. When ergonomics intervention impacts the design of a product it may result in an increase in sales. It is difficult to unambiguously calculate the impact of ergonomics design on sales, although customer surveys have been used to determine the influence of ergonomics. This may be problematic in IDCs as the general population has a very poor understanding of the concept of ergonomics and are unlikely to be able to unambiguously identify the role ergonomics played in their decision-making process in purchasing a particular product. Further, increasing sales increases a company's market share, which increases the attractiveness of the company's stock on the stock market. However, once again this is only pertinent to large-scale companies and not the smaller privately owned business more characteristic of developing countries. A major economic benefit is the reduction in injuries to customers and the concomitant product liability exposure, in other words, the cost of litigation. Again this is less applicable in developing regions.

Other less concrete benefits include demonstrating a genuine concern on the behalf of management for employees' well-being, which has the important impact of fostering what Hendrick (2003) terms "good citizenship behavior." Under these conditions, companies receive greater loyalty and commitment from the employee which results in lower levels of absenteeism, fewer grievances, and a willingness to go beyond the job description. All of these factors may have a positive impact on productivity. However, as with the product design factors, many of these factors are difficult to measure in monetary terms. Lastly, implementing an ergonomics program helps to improve the corporate image of the company, which according to Hendrick (2003), can result in better community relations and less government scrutiny.

11.2.3 Pay-Back Period

Another useful tool to demonstrate the effectiveness of ergonomics interventions is calculating the period over which the project will repay itself, an important consideration for many companies (Oxenburgh, 1997). If the intervention is considered as a once-off cost or is paid for within a single year then the pay-back period can be calculated in the number of years or the fractions thereof.

$$\text{Pay-back period} = \text{cost of improvements/net benefits}$$

According to Oxenburgh (1997), this calculation is reasonably accurate and is also financially simple, not requiring many of the factors used in capital costing. Oxenburgh further suggests that most ergonomics interventions tend to pay themselves off in about six months.

Seeley and Marklin (2003) concur, arguing that the pay-back time is surprisingly short when the relevant data were collected and interpreted.

11.3 Hindrance to Assessment of Cost–Benefit in IDCs

MacLeod (2003) maintains that the cost-effectiveness of an ergonomics intervention in real money terms will vary significantly depending on the quality of the application, the design regime, and the form of the system. Thus, in order to analyze cost–benefit, it is first necessary to gain an understanding of the risk factors for musculoskeletal disorders inherent in the respective tasks (Seeley and Marklin, 2003), and then to make assumptions about the future financial benefit. This decision can be made as accurately as possible by ensuring that it is based on the best estimate, using the experience of other enterprises, industries, parts of the same enterprise, and the ergonomist's own experience (Oxenburgh and Marlow, 2006). However, according to MacKinnon and Scott (1998), this has been problematic in IDCs as historical data and cost–benefit analysis are often used to justify past decisions rather than to make proactive management decisions.

Jensen (2002) argues that historically there has been consideration of design of products for consumers, while there has been little consideration of the worker in both the design of products and the design of the product process. Consequently ergonomics is typically only introduced when problems arise in the actual work environment. This is particularly pertinent in IDCs where the workforce is often seen as being expendable (MacKinnon and Scott, 1998). Several authors (Wilson and Corlett, 1990; Helander, 1999; Skepper et al., 2000; Jensen, 2002) provide strong arguments for the implementation of ergonomics into the design of products and the planning of the production systems. Fox (1995) reasons that ergonomics is based in academic research and we are now applying the trade in industry. Thus the challenge for the ergonomist in IDCs is to ensure that the workplace problem is assessed in the context of different cultures of workers and the conditions under which the industry exists. This is more complex than in IACs, as many IDCs are characterized by diversities in mental and physical capabilities, traditional cultural backgrounds, and long-standing working methods (Scott, 1993).

Within IDCs, there are clear barriers to the quantification of the fiscal success of ergonomics interventions. MacKinnon and Scott (1998) contend that these problems are not necessarily industry or country specific, but are exacerbated in IDCs. The accounting systems often used in IDCs are insufficient to accurately compute the costing of goods or services. MacKinnon and Scott (1998) maintain that industries in IDCs are typically using product costing techniques to determine the price per unit. Unfortunately, such systems are not favorable for determining the benefits of changes due to ergonomics interventions. Furthermore unlike industrially advanced countries, where labor costs are seen as the major cost driver, in IDCs it is the cost of imported goods and management overheads. Under these circumstances, Hendrick (1996) advocated that other indicators need to be used to assess the economic impact of an ergonomics project, such as market value of the company or company sales. However, it should be remembered that ergonomics projects in IDCs are often at a microergonomic level, attempting to implement no-cost/low-cost interventions. Under these conditions, the fiscal indicators suggested by Hendrick (1996) are not discreet enough to identify benefits of the improved working conditions.

Another hindrance to the successful estimation of the costs and benefits of ergonomics projects in IDCs exists in the poor relations between management and the labor force (Candler, 1993). The unions representing the labor force often perceive ergonomics interventions as being a means of downsizing or down-skilling by the management (not altogether unwarranted as Hendrick (2003) does sight these as potential benefits). However, this perception makes it difficult for the ergonomist to accurately collect both quantitative and qualitative data during the course of the intervention. Furthermore Loewenson (2001) contends that health problems in IDCs are often under reported due to job insecurity and a high rate of worker turnover. These problems are exacerbated by weak monitory and regulatory systems which result in occupational injuries often not being reported. The ability of the ergonomist to obtain reliable and accurate data on preintervention injury statistics in many IDCs is significantly reduced. Scott (1996) therefore stresses that it is imperative for workers to be encouraged to be part of the ongoing ergonomics evaluation and the implementation of no-cost/low-cost interventions. A participatory approach with coresponsibility at all levels of decision making needs to be undertaken for ergonomists to be successful in these developing areas. Hignett et al. (2005) demonstrate the effectiveness of the participatory approach to ergonomics in a variety of industrial settings including health care, military, manufacturing and construction production, and processing plants.

11.4 Examples of Cost–Benefit

There are a number of sources (Beevis and Slade, 2003; Hendrick, 2003; Seeley and Marklin, 2003) available demonstrating the cost–benefit of ergonomics interventions in a variety of industries including steel, electrical power industry, video display terminal users, food service, and petroleum distribution, among others. Not only have these papers effectively illustrated the benefits of ergonomics in specific industries, but also in a variety of contexts such as in the introduction of new technology (MacLeod, 2003), in the design process (Skepper et al., 2000) and the reduction of work-related musculoskeletal disorders (Hendrick, 2003). It is evident from these examples that ergonomics can be effectively implemented in a wide variety of industrial settings.

An industry which has received extensive attention in IACs is the healthcare industry, where the lower back problems suffered by healthcare practitioners from patient handling have been well documented (Marras et al., 1999). A recent study by Alamgir et al. (2008) on the efficacy of the introduction of over-head ceiling lifts to assist in the moving of patients in a Canadian hospital clearly demonstrates the benefits of such an ergonomics intervention. These authors found reductions in annual direct costs for musculoskeletal disorders from 753,302 Canadian dollars to only 294,877 dollars over a 10 year period. It was estimated that the intervention would repay itself in as little as two years if indirect costs associated with injuries are also taken into account and approximately six years when considering only direct costs. Interventions such as this could easily be implemented in IDCs and can be used as an effective illustration of how financial costs and human suffering can be reduced through ergonomics interventions. However, as with IACs, managers in IDCs will only make such procurements if the ergonomist can clearly demonstrate the financial benefits to the company.

An area of particular concern in IDCs is related to technology transfer, as cognizance is seldom taken of anthropometric differences between the source country and the indigenous population of the IDC. Hendrick (1996, 2003) uses the South African forestry industry as an example of how appropriate ergonomics input during the technology transfer process can improve productivity. The effective redesign of leg protectors to suit the diverse South African population resulted in a net cost savings of $250,000, with an estimated saving to the industry as a whole in excess of $4 million annually. The success of these interventions has prompted the South African forestry industry to remain proactive in the domain of ergonomics and ergonomics research (Scott et al., 2004). Consultancy work by Scott et al. (2004) effectively demonstrates how the provision of nutritional supplements can have a positive impact on workers' productivity. Although it is evident that sound ergonomics principles are being applied in IDCs such as South Africa, the cost/benefits of these interventions are seldom computed and even more seldom published in either academic or nonacademic journals. This remains one of the greatest challenges facing ergonomists in these regions. It is imperative for the ergonomics success stories in IDCs to receive attention in the appropriate public domains if the business world is to be convinced of their need for ergonomics.

11.5 Conclusions

There is little doubt that ergonomics can play an integral role in the economic development of IDCs, and hence in the upliftment of occupational health and safety of workers in these regions. However, to ensure the success of ergonomics, it is necessary to persuade management of their need for workplace interventions through the provision of a sound business case for ergonomics. To achieve this objective, the ergonomist needs an understanding of the costs and benefits associated with the intervention. Through interaction with human resources and accounting personnel, ergonomists can provide reasonable estimates of the costs and benefits associated with a particular intervention allowing management to make decisions based on financial terms rather than moralistic ones. Thus the introduction of sound ergonomics principles demonstrating the associated productivity and financial gains will allow ergonomics to finally have the profound impact Hendrick envisaged over a decade ago.

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12

Vulnerable Populations in Industrially Advanced Countries

Dave Moore

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Story 1: It's dark, cold and its 10.30 at night. A staff member working late on a university campus in a comfortable middle class suburb in an industrially developed country switches off the computer, leaves the place unlocked for the friendly cleaner who speaks no English, and heads for home. Out in the car park, he passes her children asleep under coats in the minibus that ferries these cleaners around the sites for their night work. A month later, a different set of cleaners appear; another contractor employing recent migrants had undercut again with an even lower price by using less cleaners or setting more work to be done for the same money. The university that contracts out their cleaning takes health, safety and well-being seriously; they run a crèche for use by staff and students, give pensions and subsidize health checks, and have a health nurse that they will send to help permanent staff set their video display unit screens at the right height.

Story 2: He's been 12 h as sole security guard at the water treatment facility. It's 7 a.m. and his replacement hasn't turned up yet. The company practice is that any guard leaving before the next man gets there is sacked. He was supposed to be home to cover with the kids. It doesn't work, and the kids are falling through the gap. This happens so often now he doesn't even call to apologize any more, and his wife doesn't bother to ask why. Their bed-times haven't coincided in months, and that worries him. He had to buy his own uniform, provide his own vehicle and pay

for his own petrol to get here. They pay him the legal minimum hourly wage, but with these expenses and the cost of living, he needs to find more and more hours to take home enough money. In the 15 years since he started work housing costs are five times what they were, but the minimum wage has increased less than 50%. Double and even treble shifting is shattering and driving home at the end of it all is dangerous. The facility he has been guarding though values its people: commissioning Safety Culture studies carried out by university researchers, and employing ergonomists to train the union health and safety representatives.

Story 3: The migrant workers, all known previously to each other from their home on one of the islands further north in the Pacific, know each other even better now after living for the season in accommodation provided by the farmer. The farmer withholds $98 a week out of their after-tax pay, with them sharing three to each small caravan on the farm; for $300 you could rent a three bedroom house in the nearby town. Last year, when they left to go home they tried to claim back the taxes that had been stopped from their wages, they found that the contractor they worked through had just pocketed their taxes himself—and not given it to Inland Revenue Department at all. They got nothing back. The contractor was a crook and the farm manager knew it, but he turned a blind eye because he needed his crops picked, and he got a kickback from the contractor anyway. By the time they had paid the farmer for the overpriced housing, costly local supermarket food and the extra clothes needed in this cold climate, they had all taken home to their families in the Islands far less than they had hoped. On the prevailing piece-work rates it had taken 15 h to make the equivalent of minimum wage for a permanent farm worker.

The above stories are all based on real details collected over recent years in New Zealand. I would argue that while we have, as a discipline, certainly neglected the struggling populations of Industrially Developing Countries (IDCs), we have also paid too little attention to those in precarious working situations in those countries considered more industrially advanced. Hal Hendrick (in a Winston Churchill-inspired moment perhaps) spoke as Human Factors and Ergonomics Society President on the potential for ergonomists as a body to improve the human condition:

> I know of no discipline where so few, if given the chance, can do so much to improve the quality of human life. We need only to look at what a small group of our colleagues has done to make aviation safety what it is today for solid empirical evidence of just part of our potential.
>
> **Hendrick (1996)**

My aim in this chapter is to present some personal thoughts on why we as a discipline, have achieved relatively little in places where it would make most difference in a global sense. First, I outline a little of what we know about those who are domiciled in Industrially Advanced Countries (IACs), but exist under conditions more familiar to those in IDCs. Second, I suggest why there may have been this disparity of ergonomics effort, and what we can do about it, individually and collectively, as a professional group.

A commitment to a systems approach is often proudly held up as a distinguishing feature of our trade. To improve the human condition among those existing outside permanent workforces though, we need to walk the walk: expand our methods, consider fully their lives in greater totality, and recognize that our work is intertwined utterly with politics—whether we are comfortable with that or not.

12.1 Hourglass Economies

The concept of intracountry variance—of development taking place at different paces within the same nation—has arisen in different contexts over time within the ergonomics literature. At one extreme, Alain Wisner used the term "Sociotechnical Island" (Wisner, 1985) to describe the insertion of a complete operational system into a foreign country by a multinational wishing to replicate its business units perfectly, with the aim of also replicating quality and performance—an island of IAC methods, standards, expectations, and conditions built as a compound in an IDC world (Guerin et al., 2007). A less dramatic, and far more common example, is provided by Apud and Valdes (1995), in Chile—here forestry workers employed by multinational firms experienced advances in working life at one pace, while those in less well-resourced local firms moved at quite another.

As Scott and Charteris (2004) point out, in our lifetimes South Africa has indeed provided a stark example of how steep a gradient can exist between the two ends of the same workforce within just one country. IDCs have pockets where good employers can provide a much better standard of work than is the norm, perhaps even with the help of ergonomists. The reverse is also true; IDC conditions, as Scott and Charteris note, can coexist for those isolated for various reasons within broader IAC settings. Where this occurs, the population in question fall into the category of precarious or vulnerable workers—those paying the prices of a wealthy country while being denied access to the benefits.

Internationally the catch cry of "job creation" was modified in the late 1990s by the ILO launch of a new agenda for action that focused on the quality—"Decent Work"—as well as the availability of work. The Organization for Economic Cooperation and Development (OECD, 2002) confirmed that "dependent employment of limited duration" had been increasing also in the wealthier nations in the previous two decades, and the call for Decent Work for those caught in the trap of precarious jobs, was therefore echoed in countries such as Australia (Pocock et al., 2004) where previously it would have been thought unnecessary. The new climate was widening the social divisions through mechanisms which also reduced mobility between them. Trevor Phillips, Chair of the Equality and Human Rights Commission in the United Kingdom, recently described the polarized state of the workforce in that country as an "hourglass economy (which), is the issue of the twenty-first century, the divisions between the haves, the have-nots, and the never-will-haves" (Phillips, 2008). Added to the age-old problems for migrants from IDC therefore has been the more marked emergence of two-tier labor markets in the wealthier nations; those in secure core (standard) employment, and those low paid nonstandard employment. There is a growing hidden, shifting workforce that attracts little or no investment from employers, and appears far less than it should on government radars.

12.2 Precarious/Vulnerable and Nonstandard Work

The terms "precarious" and "vulnerable" appear to be used interchangeably. Precariousness is more commonly used in New Zealand and is defined by Tucker (2002) as "employment that is low quality and which puts workers at risk of injury, illness, and/or poverty (from low pay and little opportunity for training and career progression)." Nonstandard work is

that which is not full-time and permanent, but includes high-earners who choose to leave employment to consult etc. Those in nonstandard roles are therefore not all in precarious employment, but for those on low pay, nonstandard conditions make it more likely.

12.2.1 Indicators

In New Zealand, the following indicators of precarious work have been proposed by New Zealand Department of Labour (Tucker, 2002):

- The job can be terminated with little or no prior notice by the employer
- Hours of work are uncertain or can be changed at will by the employer
- Earnings are uncertain or irregular
- Functions of the job can be changed at will by the employer
- There is no explicit or implicit contract for ongoing labor
- There is, in practice, no protection against discrimination, sexual harassment, or unacceptable working practices
- The job is low income—at or below minimum wage
- There is little or no access to "standard" employment benefits such as sick leave, domestic leave, bereavement leave or parental leave (any leave that is accrual-based will not build up if their contract is repeatedly renewed at short intervals—even if they in fact work solely for the same employer as a casual, temporary or fixed-term worker for a year or more)
- There is limited or no opportunity to gain or retain skills through access to training and education
- The task performed or the health and safety practices at the workplace makes the job unhealthy or dangerous

Seasonal workers and service workers are the most likely to be found engaged in precarious employment in New Zealand, and the seasonal sector is a large one proportionately, 40,000 workers (more than all the country's nurses) are needed each year in New Zealand. Typical work settings with these indicators also include construction sites, call centers, contract cleaning, and on-hire labor work. The labor market, since the Employment Contract Act of 1991, allows more blurring of employment relationships. Contractors, for example, who in reality are not self employed as they are tied to one employer; courier drivers and other vehicle owner-operators may be in this position (Mackie and Moore, 2008). Triangular relationships in the construction industry are common, with on hire labor firms positioning themselves as "just the broker" between building firm and laborer, with predictable uncertainty in the minds of the laborers about who is responsible for safe systems of work.

12.2.2 At-Risk Groups

The people most likely to be found in precarious work are:

- Women (not found to be over-represented in all countries due to heavier manual jobs being predominantly held by males)
- Youths

- Ethnic minorities
- Recent migrants
- Less skilled and educated
- Less well informed about employment rights and less capable of bargaining effectively
- Less likely to be unionized

12.3 The International Picture

There are similar reports from countries other than New Zealand. The Secretary General of the British Trades Union Congress (TUC), recently identified "legal and regulatory flaws" as the factors that were keeping "two million workers in conditions which shame a modern economy" (Barber, 2008). This, "hidden army of vulnerable workers" is "trapped in a cycle of low-paid and insecure work, where mistreatment is the norm." (Commission on Vulnerable Employment—CoVE, 2008). The Commission report noted that the scale of the situation had taken them by surprise. "All the Commissioners—whatever their backgrounds—were shocked at just how vulnerable some workers are in today's Britain" (Barber, 2008). A major review of studies specifically on migrant work in the expanded European Union (EASHW, 2007) have found that both internal and wider immigration patterns are fuelling the problems. Despite inconsistencies in the literature due to problems in obtaining reliable data, the overall conclusion is that health, conditions and accident rates are higher across the EU than for those nationals in core roles.

Reports from the United States paint a similar picture, with an estimated (Tucker, 2002) one in ten now in nonstandard work arrangements. Union studies there (AFL/CIO, 2005) emphasize the even more dire circumstances faced by the undocumented people (illegal immigrants and those working contrary to visa requirements) in the workforce, who may number as many as 10–12 million. The use of undocumented workers appears more acceptable, if not essential, in the eyes of employers faced with staff shortages when looking for seasonal workers. In Europe the number of undocumented workers has doubled since 1991. Estimates now suggest 6–8 million in the 25 countries of the EU are undeclared (EASHW, 2007).

Comparative studies investigating the pay and conditions of undocumented working people in Australia, the United States, and the European Union have indicated greater exposure to exploitive and unsafe employment practices (Guthrie and Quinlan, 2005). In Britain the CoVE (2008) asserts that the tacit approval of the need for an underclass to keep businesses competitive is not acceptable. They "reject the argument that vulnerable employment is the price that has to be paid for national prosperity."

Australia has experienced intense migration since the Second World War, and researchers have taken steady interest in the integration of migrants into the workforce over this time (Quinlan and Lever-Tracy, 1988). Interviewed in the New Zealand trade press this year, Michael Quinlan of the University of New South Wales, suggested that the situation had deteriorated in that country (Bell, 2008). "The way business has reconfigured the framework of employment means all workers—both blue and white collar—are again more vulnerable." And with foreign workers "there are lots of positive incentives to bring them in and take advantage of them." Contract cleaning in Australia has been highlighted

(LHMWU, 2004; Wiegall et al., 2005); as it has in the United Kingdom (Woods et al., 1999) as one example of a sector suffering from "work disorganization"—to borrow a term from Michael Quinlan.

12.3.1 Stepping Stones—Or Traps

Research on the circumstances of those in precarious work internationally, reports consistently that nonstandard workers earn considerably less than those in full-time permanent employment (OECD, 2002). It is therefore essential that in each context in which we find precarious jobs, we know whether they are "stepping stones" into standard work, or whether they are "traps," in which the lack of progression through training and opportunity combines with damage to health and wealth, to weaken their prospects further. The review of the literature by Tucker (2002) finds evidence of both scenarios among the studies published, and they seem to be clustered by country and by industry. The conclusion appears to be that neither employers' associations nor labor advocates consider the work offered in the precarious nonstandard sector to be a long-term option for an individual.

The argument for nonstandard work hinges on flexibility. The smaller companies in particular, argue for the need to be able to respond to opportunities in the market by having an unpaid pool available to draw on that allows them to take on people quickly from day-to-day in order to stay competitive. And there are many small firms in New Zealand; the Statistics New Zealand 2007 Business Demographic Statistics indicated that 97% employed fewer than 50 people. However, this leaves the door open for exploitation by those employers, such as cleaning contractors, for whom it is possible by careful arranging of short-term individual contracts to have no one ever on the books as a permanent staff member. The figures can also be used mischievously, giving the impression that the economy is driven by the very small companies, and so regulation needs to be tailored to their needs. But that is not the full picture, 80% of firms may employ fewer than 10 people, but these businesses only account for 19% of the total workforce. The biggest gap in our knowledge is that we have no data on the long-term outcomes for those who are trapped (Tucker, 2002). Given that the studies on short-term exposure have already demonstrated more problems with health, personal and family relationships, quality of life, and general well-being, any research on the lifetime worker welfare of this group would doubtless make grim reading.

12.3.2 Reasons for the Increase

> There is hardly any change that has not been (called) progress by somebody.
>
> **Henderson (1941, p. 248)**

The increase in numbers of those in precarious employment over the last 15–20 years has been attributed to a number of factors, the analysis further complicated by differences in the way each country defines and measures its workforce (Tucker, 2002). Increased globalization of markets, and a rise in neoliberalist attitudes, are seen though by many writers as the intrinsic factor behind the increases. Political journalist Paul Mason speaks of the newly enlarged casual workforces "summoned into existence by free trade" (Mason, 2007, p. 184). Attendant to this is a decrease in union membership. Whether a weakening of union influence allowed in more nonstandard work, or the other way round (that the creation of more nonstandard work reduced the bargaining power of the unions),

is debated in the literature. James et al. (2007) describe the process as the "fragmentation of previously integrated systems of production and service delivery" over the last three decades. A process which has had adverse implications for health and safety through the increase in the use of temporary staff is self-employed workers and home-based workers. In New Zealand certainly, reduced regulation in the 1990s was designed to assist business be "lighter on their feet" and better able to respond to market changes. The changes in part have been seen as welcome flexibility, defending and extending options for good-quality part-time work, for example by Pocock et al. (2004) in Australia. The same authors note however, that other changes that came about were "less welcome and less necessary"; notably, the emergence of "dependent contracting," greater "permanent casual" work and the incursion of labor-hire arrangements into certain industries.

In New Zealand, we have also seen an increase in hours by those in permanent positions, ranking second behind Japan as the OECD country with the highest proportion of employees working over 50 h a week. At the same time the rise in part-time and temporary work has increased the number of jobs offered that do not pay enough on their own to provide an adequate income. Goldenhaar (cited in Drury, 2008) refers to a similar situation in the building industry as the Goldilocks model—either too hot, or too cold. Most employees appear to want a steady 35–40 h with a single employer, allowing commitments outside work to be honored, but even for those in core jobs is increasingly elusive in New Zealand. The traditional egalitarian New Zealand expression "Jack is as good as his master" was heard often in debates in the 1980s and 1990s as Sunday trading increased, making involvement by retail workers in weekend family, religious, and community activities more difficult. Until the early 1990s shops had a late opening night during the week, but then closed for the weekend at lunchtime on Saturday. Such restrictions have now gone.

Adding to the long-term pressures on families in vulnerable populations in New Zealand were philosophical shifts in social policy, made at around the same time as the changes in workplace regulation. Income-related rents for tenants of State-owned housing were replaced by rents calculated on market prices for most of the 1990s. This period saw a reverse, in the most socially deprived areas, of the positive national trend toward less overcrowding in housing. Over-occupancy had been declining in New Zealand generally, but during this decade close-contact infectious disease cases doubled; the research community pointing to lack of affordable accommodation for low-end earners and increasing socioeconomic inequality generally as the causes. The disease types emerging included those more commonly associated with neighboring IDC. Measures of the growing social gap in New Zealand were alarming. Inequality based on income rose more here than in any other OECD country (Kiro, 2008).

In the decades prior to the 1990s, the form of work in IACs was not a matter for common study, as what constituted desirable terms and conditions were largely taken for granted (Pocock et al., 2004). Deregulation brought out once again into daylight, questions about basic good practice in the design of work that had gone undebated for most, if not all, of the last century in IACs. In the United Kingdom for example, the requirement for ethical purchasing practices in the public sector was dropped. The rescinding of Britain's Fair Wages Resolution (FWR) (1946) by Margaret Thatcher's Conservative Government in 1983 marked the end of an era. Since its adoption in 1891, the Resolution had required those contracting to government departments to "pay rates of wages and observe hours and conditions of labor no less favorable" than those enjoyed by workers employed under collective agreements in the same trades in the locality where the work was carried out. This change was followed up by the Local Government Act (Section 17), which actively

prohibited local authorities from taking into account "noncommercial matters," such as terms and conditions of employment in their procurement practices. James et al. (2007) conclude that despite clear weaknesses in the FWR, the intent was right, placing responsibility on those at the head of the supply chain to require minimum standards of its suppliers. The compulsory competitive tendering of the 1980s and 1990s by parts of the U.K. public sector after the Local Government Act (Section 17) led to cuts in the remuneration of those employed on tendered work.

12.4 Milk and Honey? The Heightened Risks for Migrants

By 1994, the United Nations noted that there were more people on the move as migrants than in any other period in history (Moray, 1995). As migrant workers over the centuries have discovered, the GDP grass may be greener overall where you are going—comparatively a land of milk of honey—but life at the bottom of the social ladder in that land may prove disappointingly familiar. Social support mechanisms in IACs certainly offer a safety net in principle, but they are designed primarily for fully documented citizens of those countries. They rarely, if ever, offer the same protection to new arrivals. In New Zealand certainly the principle is that migrants arrive to work, not to "bludge" on the state. Full unemployment benefit, for example, is only available to people who have continuously lived in the country as citizens or permanent residents for at least two years. For the migrant there are additional problems that will make it harder to get ahead: language problems, general ignorance of the country and its ways, prejudice when applying for jobs or loans, absence of extended family around to help out, lack of working capital, homesickness, and being shunned by those already struggling there to whom new arrivals are just more unneeded competition.

Studies in the United Kingdom by the Health and Safety Executive (McKay et al., 2006) have also identified a number of specific factors that place this particular group at greater risk of injury and ill-health:

- They are likely to find work in occupations already recognized as high risk, such as construction
- They are new to the job
- Speed of learning is hampered by not being able to understand their supervisors and manuals, warnings, and labels well enough
- They are there to earn the most money they can in the shortest time

Most migrant workers worldwide therefore end up in the "3-D sector" doing jobs that are dirty, demanding, and demeaning. And they remain largely invisible in national and regional data, despite being numerous—191 million globally, according to the ILO (2007) International Migration Programme. Migration is not evenly spread of course, some countries attract far higher numbers. For example, one in five of the current New Zealand workforce was born overseas. Internal migration in large countries (e.g., China 121 million), forms a large part of this picture, and here migrants often experience similar working conditions and problems as are experienced by international migrants. India similarly has

substantial internal migration. As described already irregular (illegal) migration, leading to undocumented working, predictably renders the migrants even more vulnerable to exploitation than they were already.

12.5 Ergonomists as Part of the Problem

> …the experience of all highly developed sciences shows that the clear, explicit formulation of 'the obvious' and its incorporation in the systematic treatment of a subject is both necessary and very convenient. We are all liable to neglect, or overlook, or forget such things, especially when we wish to, and above all when we so wish unconsciously.
>
> **L.J. Henderson. In: Barber (1970, p. 62)**

I suggest there are several ways in which we have contributed to the growing divide between haves, have-nots, and never will haves:

Overall, we haven't worked with the people who need ergonomics the most. Some areas of activity have received far more attention and resources than others. Half of the human working population in this world work in agriculture, or closely related activities; and this sector, hugely underreported as it is, still accounts for at least half of all workplace fatalities. A cursory search of the 97,000 entries in Ergonomics Abstracts in 2006 found just 0.4% had any keywords relating to farming activities. If we had had the same success in agriculture as we have in aviation since the 1950s, there would be around 130,000 less farm worker deaths per year worldwide (Moore et al., 2006).

We have said one thing—done another. The ultimate aim that most of us would I suggest agree with, is improving the human condition (or quality of life according to the IEA). This aim is at odds with the real motives of those who personally write our wage check; which are to ensure improvement in performance in already highly performing areas, and in improving the competitiveness of individual companies in their given market.

The "World Series" effect. Ergonomics work written up in languages other than English, or emanating from poorer countries has not been allowed into the body of knowledge with the ease that it should. The fact that we can claim in our PhD theses to have established the state of knowledge in a given topic, after reviewing the literature of just one language is remarkable, and disappointing in my view. Some countries have obviously enjoyed far more activity than others, the development and application of ergonomics has not been evenly spread. However, conference proceedings and journal publications are not an ideal way to gauge the true picture of what has been done. Conferences take place in the costlier nations, as a rule, and so are expensive to attend. Journal paper writing is costly in time, especially if English is not ones first language. Employer tolerance for this will be linked to the amount of fat in the system. A colleague of mine specializing in forest ergonomics studied Russian a few years ago in order to be able to learn more from the papers published on that topic in that region. There are French researchers, who as a matter of principle publish only in French, I am told, which is fair enough. Ergonomists from non-French speaking countries wishing to establish the state of knowledge on issues to which these authors contribute, either make the effort to establish what advances have been made, or acknowledge that their review is not actually comprehensive. There are 360 odd recognized languages in the world I gather, and I am not suggesting that one needs to be able to

read every one of these, but when we find people doing important work that is not being published in English, surely it is just simple arrogance to disregard it. Internet-based translation systems will hopefully help us more cheaply overcome language barriers.

Disregarding vulnerable workers. As ergonomists we are drawn from populations well-practiced in turning a blind eye, and we are not immune to it ourselves. Also, there are specific inducements to disregard the precarious work sector:

- Industry is not offering to pay for it. They are easily replaced and there is fast turnover, hence there is no reason to invest in and protect them—the opposite of military pilots.
- Permanent staff will get pushed forward by supervisors in preference to those in the vulnerable sector when ergonomists visit the plant to do studies; "it's not worth talking to casuals—they won't be here tomorrow."
- Profitability may be reliant on the cheap labor which precarious workers provide—"don't want to open a can of worms."
- Government has not been asking ergonomists to look at the problem, which to them is largely invisible. The precarious workforce in cleaning for example is currently split between several pools of data so statisticians don't know where to look, and the data would be unreliable and understated if they did. Underreporting is endemic.
- The Unions, until recently, were not arguing for them, as too few were members.
- They are not a conveniently easy population to study. They are hard to contact as they move a lot, struggle with the language, verbal or written, are hard to pin down for interviews, and may be generally wary of your intentions. People on the edge of getting by financially are often reluctant to be identified; they are worried about their legal status or of being sacked for talking, and are maybe also claiming benefits illegally.

Our approaches to studies with a specific company rarely take a truly systems approach and often lack integrity. To a great an extent we answer "management-defined problems" (Vitalis et al., 1998), acting as "willing collaborators, conforming to managerial perceptions and imperatives." Vitalis, writing about the 1980s, attributed this willingness partly to the relief of finally feeling "wanted" by managers. As a consulting ergonomist, the least welcome message to deliver to a manager is that their decisions have not been good; it is easier telling them that new equipment is needed (they probably didn't choose the desks anyway). The easiest and most welcomed finding is to be told that their staff need to change their behavior. None of us like to be criticized, but when we accept the management definition of the problem as our brief, we are already narrowing the scope to parts of the system that the manager is willing to accept criticism of. When the individual is asked to change rather than the broken machine, the central tenet of ergonomics is violated (Welford, 1976).

In the New Zealand meat industry, a 25% turnover of staff a year is not uncommon. A study by (Slappendel et al., 1996) looking at musculoskeletal disorders in the boning room of a beef plant, was followed up a year later by a repeat series of interviews with all staff. At the time it was rare to have many people over 40 years old in the job as they "wore out" due to the physical demands. The study was part of a national effort to gain a better understanding of the nature and extent of injury and ill-health in meat processing in New Zealand. The interviews should have included those who left the job during the year. If underemployment of ex-meat-workers through serious incapacitation

or predisposition to subsequent injury was placing a burden on the social services and families, then clearly this was an important part of the overall picture. Such a study would have required the coordinated cooperation of the industry, the community, and several government agencies. It was not attempted then, due to cost and logistical difficulties, and has not been since.

12.5.1 What Could We Be Doing as Ergonomists?

> …the approach centred only in tools, machines, work places and work organisation seems not to be the best model for developing countries. Although it is necessary to make forest work safe and more profitable, it is also very important to find strategies for making the social environment of the workers and their families of better quality…raising the conditions during the hours of work is of limited value if the overall living conditions of the community remain significantly substandard.
>
> **Apud (2009)**

As Elias Apud points out, we are of course largely wasting our time if we are trying to improve the human condition by easing the load of workers during eight hours of their day, while they are go backward for the other 16. It is painting over the rust. The ILO Director-General stated recently "Respect for workers' lives must be at the heart of sustainable strategies for growth and development" (Wickramsekara, 2007). The important emphasis here is on workers' lives as a whole—not just their working lives. As has been known and practiced in IDCs for many years, those seeking to genuinely improve the human condition of people at the bottom of the social ladders in wealthier countries also must broaden their vision by adopting a genuine systems approach.

The U.K. Trades Union Congress Commission on Vulnerable Employment recommends:

- Improved awareness and advice
- Better enforcement of legal rights
- Better regulatory and legal protection and union representation
- Guaranteeing rights down the supply chain

The following points, in no particular order, suggest what we might do as a discipline to start applying the systems view we have always spoken about, and in doing so help the vulnerable sections of the workforce. Ergonomists, I believe, need to:

- Collaborate with colleagues from related fields on long-term research needed on the affects of precarious employment on the lives of working people and their dependents.
- Put more research efforts into learning how to apply what we already know. To use an IDC analogy, we do not need more research to find out technically how to provide clean water for everyone. We know that well enough, but how to generate the political will to prioritize clean water provision is the real question. The long-term performance, health and family sustainability problems associated with the working conditions now experienced by vulnerable workers in IACs were understood well enough a century ago. How we shape a social structure within which creating such roles become unattractive is the real question here surely.

- Push for, and support, changes in regulation and policy that make the precarious workforce more visible through national and regional surveillance strategies. This may include pressing for consistent funding through levies in high-risk industries.
- Engage with those in related fields who are working to improve health and safety by careful regulation of the supply chain where the fragmentation of previously integrated systems of work is proving especially problematic (James et al., 2007). The positive experiences of this approach in a number of countries are encouraging. In particular we should look, I believe, to the public sector to lead by example with its own procurement processes. There are historical models for this including the U.K. Fair Wages Resolution (1946)
- Encourage a more consistent industry-wide approach to dealing with systemic problems. Individual firms will be unable to afford implementing beneficial changes that increase costs unless their competitors are required to do the same; the level play field is maintained. Unless rules are enforced that apply to all, bad employers will remain able to undercut good ones. As Brendan Barber, of the (U.K.) Commission on Vulnerable Employment states "good employers have nothing to loose—and much to gain—from policies that stop them being undercut by bad employers who break the law or use loopholes to get around it" (TUC, 2008).
- Initiate meaningful international collaboration with ergonomists working in the countries of origin of migrant groups, when working with immigrants to help avoid inappropriate interventions and/or implementation approaches, overcome language and cultural differences that can lead to misunderstandings and underreporting.

Ergonomists in IACs can also do more to assist colleagues and others working in IDCs. For example:

- Collaborate with ergonomists down specific supply chains. As Peter Buckle (Surrey University) noted in an unpublished address on "Issues and Challenges Facing the Discipline" at the IEA Triennial Congress in Maastricht 2006, "problem processes" in industry are being shipped out to countries with cheaper labor and, more importantly, less regulation. Communication between ergonomists in the two locations would be advantageous to companies suitably motivated to minimize risks while reducing costs.
- Use cheaper methods of international networking.
- Encourage the publication of work from IDCs.
- Increase inclusivity within our professional bodies; participation in IEA Council debates still requires the physical traveling to a hotel in an expensive part of the world, when a third of the people who should be there are unable to afford to get there. This is archaic.
- Support ergonomics education programs in IDCs that are of international standard. Forty years ago Corlett (1968) noted that obtaining training was easiest for those also wishing to leave their home country; a situation which is evident despite advances in technology.

Beyond helping vulnerable populations, or IDC workers in general, the larger question of our role in global sustainability remains largely undebated, and entirely unformed at a collective level. Raising everyone's pattern of life to the wasteful excesses of the West will not achieve long-term sustainability.

We need to look for new approaches, and new roles within these. Providing social indicator data in life-cycle assessments of products could be one of these. There was a landmark report in 1987 by the World Commission on Environment and Development (WCED), chaired by Norwegian Prime Minister Mrs. Gro Harlem Brundtland, which called for Sustainable Development "consistent with future as well as present needs." Since then, life-cycle assessment methodologies, designed to educate consumers and support decision making between competing products have moved on, from a focus almost solely on environmental sustainability, to adopt and holistic approach that also incorporates economic and social aspects. "Consumers are increasingly interested in the world beyond the product they buy. Life-cycle thinking implies that everyone in the whole chain of a product's life-cycle, from cradle to grave, has a responsibility and a role to play, taking into account all the relevant external effects. The impacts of all life-cycle stages need to be considered comprehensively when taking informed decisions on production and consumption patterns, policies and management strategies." Klaus Topfer former UNEP Executive Director (UNEP/SETAC, 2008).

Ergonomists are well equipped to take on roles in this type of exercise, which call for the ability to marry qualitative with quantitative methods within a systems approach. Ergonomists have more experience than either the chemists or social scientists who have been struggling with this for over a decade. Where have we been while this was going on? Certainly, we have not been engaged anywhere near enough in the multidisciplinary research efforts that numerous ergonomists have urged us to over the years. We have played it too safe.

Ultimately, if no one is offering to pay for it, we may have to improve the help we give to people in neglected sectors, be they IDCs or vulnerable populations in IACs, by giving some of our time for nothing. Visionary industrial designer and educator Victor Papanek (1926–1999) considered the design output of his adopted America "inconvenient, often frivolous and even unsafe" (Papanek, 1971). In his first of several books on social responsibility and the design community *Design for the Real World: Human Ecology and Social Change*, he asked how the designer, who must make a living (like others), could actually serve the "real needs" of human beings? "I have tried to demonstrate (he concluded) that by freely giving 10% of his time, talents, and skills the designer can help." (Papanek, 1971.) His projects included: A prototyped educational television set that could be utilized in IDCs and produced for $9.00 per set (cost in 1970 dollars), and a transistor radio, that could be made from ordinary metal food cans and powered by a burning candle. We cannot rely on market forces to steer us as ergonomists into socially responsible roles.

Hardest of all, we may need to couch our most basic tenet *fitting the task to the man* in a broader one. Neville Moray (1995) asked "…have we (as ergonomists) failed to notice the larger picture. Have we no underlying philosophy…?" In a world where what we as humans want, and what we can afford to give, is clearly out of balance, Moray identified a new role for us—as designers of life-style support systems that elicit the desired behaviors that will achieve sustainability. We cannot have infinite aspirations in a closed finite system. We may find our underlying philosophy needs to be not only fitting the tasks to mankind, but also, fitting mankind to the planet.

12.6 Conclusions

As the stories at the start of this chapter illustrate, to address the current situation regarding vulnerable populations in IACs, we have to look beyond their primary workplace. To a great extent though, our toolkit as ergonomists has been designed on the assumption that we will be dealing only with the standard work conditions prevalent in Western Europe and North America following the Second World War.

The emergence of the "Hourglass Economies," with retracted social mobility and tougher welfare provision has presented us in IACs with a new situation. One where we have far fewer households with a single wage earner working a 40 hour week, and far more domestic settings in which multiple adults are working multiple nonstandard jobs. The risks of exploitation have risen, especially for migrants, and there are more of these than ever before. Our methods have not moved in line with these changes. We do not as a rule investigate work-life balance, or multiple jobs ("moonlighting") enough in our studies. As ergonomists we have contributed to the current situation. There may well have always been a lag between innovation and exploitation (Stanton and Stammers, 2008) in the uptake of ergonomics research, but I suggest that there has also been a lag between our approaches and the social context in which we operate. We may have spent 50 years developing an excellent toolkit to learn about the world of manual work—as it was. It is also possible that financial necessity, market forces and professional expedience have proven irresistible. Whatever the reasons may be, we have not worked enough with those who need our help the most, be they in IDCs or IACs.

I would argue that we need to look wider, act wider and collaborate more widely. The approach has to be more holistic, one which encompasses, as a matter of course, both the working life and the life outside work, of the people we seek to serve. The scope of our implementations and professional associations has to change. We know that (Tappin in press) multifactorial problems need multidisciplinary answers, and yet we too rarely find ourselves in the teams needed to make these changes happen. "Income is the single most important determinant of health" (National Health Committee, 1998, p. 23); not bad posture, lack of task rotation or goal conflicts. And yet, certainly in IACs, we too often fight shy of the issue. Little else seems to be outside our scope, but take-home pay is. It is our business whether they get paid on an hourly or piece-work rate, but the total is not; even if that results in their children living in poverty, as 22% in New Zealand now do (Kiro, 2008).

Philosophically, I would argue that we need to mature as a discipline; to adopt and work toward, as Moray (1995) suggested, not only a philosophy of design, but also a philosophy of values. We have shown collective neglect of vulnerable populations in IDCs, and more latterly in IACs, where we could have done more to improve the human condition. These acts of neglect, I believe are not themselves indicators of an absence of potency, they are more the symptoms of an underlying philosophical poverty in our discipline of ergonomics.

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Part IV

Application in Specific Industries

13

Vibration Characteristics of Tractors and Power-Tillers: An Ergonomics Perspective

Vilas M. Salokhe, Madhav D. Gholkar, Peeyush Soni, and Hiroshi Nakashima

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13.1 Asia at a Glance

Agriculture has been a backbone of developing Asian economies. However, there is constant increase in population and its demand for food. The growing urbanization and industrialization is also resulting in shrinkage of agricultural areas. This is causing pressure on farmers for intensive farming. The mechanization of farms is inevitable and many Asian countries started farm mechanization in the early 1950s.

13.2 Human–Machine–Environment Interactions

The use of humans and animals in agriculture in the past has been replaced by modern machines. Efficient equipment and machines such as tractors have been developed. These have changed the characteristics of agricultural labor and have affected the workloads on the operators. To speed up operations, emphasis is given to machines with higher outputs per unit time and bigger size or capacity. However, this can cause an increased load on the operators resulting in occupational hazards leading to impaired performance. In addition, farmers are not only subjected to fatigue and discomfort due to physical labor, but they also suffer from the adverse effects of vibrations and noise (Huang and Suggs, 1967). The number of tractors, harvesters, and threshers for selected Asian countries is shown in Table 13.1. In mechanized farming three main components are involved: humans, machines, and environments. For efficiency, there needs to be good coordination and interaction among these components. Generally in developing countries, ergonomics and safety in agriculture are neglected. Hence, the study of human–machine–environment in agriculture with an ergonomics perspective is long overdue.

13.2.1 Human Aspects

One of the most important inputs for mechanized agriculture is human-power. Thus, for any development in the mechanical power domain human aspects should be carefully considered, for example, the working capacity of humans is influenced by their body strength, physical workload capability, visual and hearing abilities, vigilance, and endurance. Usually, environments that exceed these limits cause premature fatigue, impaired health, and increased possibility of accidents. Figure 13.1 shows a schematic of the human–machine–environment system and interactions among them. Humans, as well as machinery, are subsets of the environment, so any change in environmental conditions will affect humans as well as machines.

13.2.2 Machine Aspects

The use of machines in agriculture modifies the way in which operations are performed by the farmers. It increases precision and accuracy as well as increasing the quantity and

TABLE 13.1

Number of Tractors and Harvesters–Threshers per 1000 ha of Arable Land in Selected Countries of Asia

	Year									
	Number of Tractors (Number per 1000 ha of Arable Land)					Number of Harvesters–Threshers (Number per 1000 ha of Arable Land)				
Country	1979–1981	1989–1991	1999–2001	2001–2002	2002–2003	1979–1981	1989–1991	1999–2001	2001–2002	2002–2003
Bangladesh	0.5	0.6	0.7	0.7	0.7	N.A.	N.A.	N.A.	N.A.	N.A.
Cambodia	0.6	0.3	0.6	0.7	0.7	0.01	0.005	0.005	0.005	0.005
China	7.6	6.7	6.4	6.5	7.0	0.279	0.322	1.695	2.188	2.539
India	2.4	6.1	12.1	13.6	15.7	0.009	0.018	0.026	0.026	0.026
Japan	272.3	430.6	460.1	459.0	461.2	174.3	254.7	238.7	235.9	237.0
Korea (N)	19.6	29.9	24.9	23.8	23.8	N.A.	N.A.	N.A.	N.A.	N.A.
Korea (S)	1.4	21.4	111.4	124.1	128.5	0.623	22.3	50.7	52.6	52.8
Lao PDR	0.7	1.1	1.2	1.2	1.1	N.A.	N.A.	N.A.	N.A.	N.A.
Mongolia	8.2	7.9	4.2	4.2	4.2	1.894	1.700	1.025	0.960	0.960
Nepal	2.4	6.1	12.1	13.6	15.7	N.A.	N.A.	N.A.	N.A.	N.A.
Pakistan	5.0	12.7	15.0	14.8	16.5	0.025	0.073	0.075	0.074	0.822
Philippines	2.0	1.9	2.0	2.0	2.0	0.084	0.120	0.124	0.123	1.23
Sri Lanka	14.1	7.5	9.9	11.5	11.5	0.003	0.007	0.011	0.011	0.011
Thailand	1.1	3.3	13.9	13.9	15.6	1.091	2.393	4.380	4.380	4.918
Vietnam	3.8	5.1	25.0	24.7	24.4	N.A.	N.A.	N.A.	N.A.	N.A.

Source: FAOSTAT, 2004. Available online at http://faostat. fao.org/

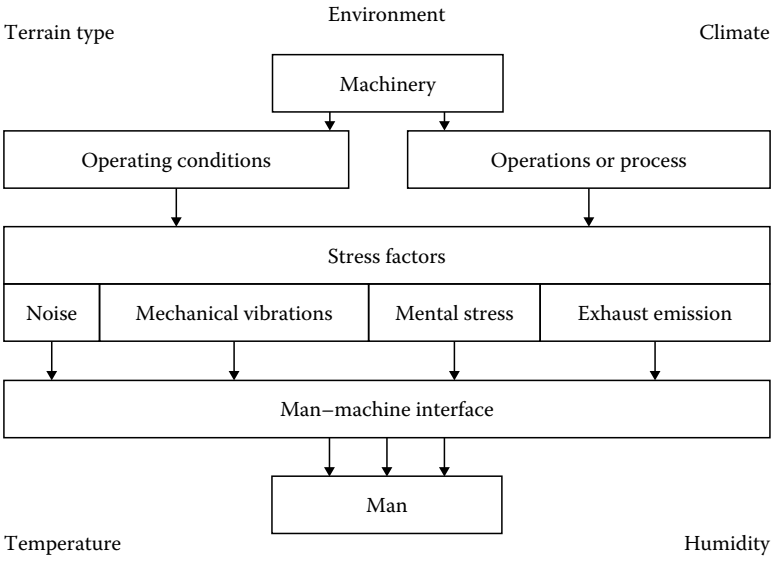


FIGURE 13.1
Man–machine–environment system and their interactions.

quality of work. However, sometimes working conditions demand increased attention and skills which may exceed the tolerance limit of human physical and mental stress, leading to occupational hazards, diseases, and reduced performance. The vibrations and noise produced by the machines can cause additional problems to the operators.

13.2.3 Environmental Aspects

The environment includes all factors in the surroundings which have direct and indirect effects on humans as well as machines. It has long been recognized that the working environment of laborers has a significant effect on their ability to perform their task efficiently. Unfavorable environments (especially hot and humid) impose physical loads on an individual (Suggs and Splinter, 1961). Moreover agricultural workers suffer from noise and vibrations which could impair their hearing ability and deteriorate their performance and health.

13.3 Use of Tractors and Power-Tillers: Benefits and Drawbacks

Agricultural tractors and power-tillers (two-wheeled single-axle tractors) are extensively used for on-road and off-road transportation and for different field operations including normal cultivation tasks such as powering threshers, pumping water from wells, pesticide and fertilizer application. The durability and versatility of these machines are the main reasons for their extensive use (Chaudhry, 1991). Due to their suitability for small farms, their versatility, and lower investment requirements, power-tillers are popular in most of the Asian countries. There are some substantial shortcomings of tractors as well

as power-tillers. An operator working with a tractor or power-tiller for long periods has to endure various stresses. It is widely recognized that tractor operators are exposed to high levels of whole-body vibration (WBV) during farm operations (Scarlett et al., 2007) which causes short- and long-term effects on the health of operators. These operators have to endure very suboptimal postures while driving a tractor or power-tiller. Walking behind the power-tiller during field operations imposes a greater workload on the operator and results in fatigue (Salokhe and Mamansari, 1995). The noise generated during farm operations is another cause of operator fatigue. Hwang et al. (2001) reported that farm noise exposure is a serious risk to the hearing of a worker.

Various studies underline the importance of ergonomics considerations for improving the safety and comfort of tractor operators. If the machinery and operator controls are not properly designed to suit most of the population, the performance demanded may quickly reach, and even exceed, the limits of tolerance. As a result of excessive stress, premature fatigue and impaired health, and the possibility of accidents will increase (Dupuis, 1959). Hence, it is important to conduct scientific studies based on ergonomics assessments to improve the working conditions of tractor operators.

13.4 Theory of Vibration

Vibration occurs in all moving bodies, and tractors or power-tillers are no exception. Although the engine is the only source of excitation of vibrations in a stationary condition, its different moving parts vibrate at different frequencies depending on their own degree of freedom and the natural frequencies which contribute to the further vibration of the whole system (Salokhe and Mamansari, 1995).

Vibration is the rhythmic oscillation of a mass. The vibrations can be sinusoidal or random (Sanders and McCormick, 1987). Sinusoidal vibrations are regular in nature and predictable. Random vibrations are irregular and unpredictable. The latter are the most common type of vibration experienced in the real world. Specifically with tractors, vibrations result from the interaction of the vehicle with the rough terrain, and from its own power source (ISO standard 2631-1: 1985). Vibrations due to the rough terrain may affect the whole body of the operator. WBV is the most common form of vehicular vibration. The nature of the terrain surface profile typically induces low-frequency, high-amplitude vibration to the vehicle; whereas high-frequency, low-amplitude vibration is induced by the engine and other moving parts (Wolken and Yoerger, 1972). Low-frequency, high-amplitude vibrations severely affect the human body, more so than high-frequency vibrations because most of the body organs have natural (resonance) frequency in the range of low-frequency vibrations.

Low-frequency tractor ride vibration results in driver discomfort and the possibility of spinal injury. The vestibular systems are affected by low-frequency vibration which results in instability, disorientation of body, and disruptions of vision (Anthonis et al., 2000). Experimental studies on the transmission and tolerance of vertical vibrations, caused by tractors, indicate that the tractor operator is exposed to low-frequency (0.5–11 Hz) and high-intensity vibrations, which are harmful to the body, causing disorders of the spine and supporting structures.

Generally light machinery or hand-operated power tools are more liable to produce high-frequency low-amplitude vibrations. Heavy off-road machines are only excited by

low-frequency terrain undulations. Increase in speed, or extremely rough terrain contributes to the generation of high-frequency low-amplitude vibrations. Vasomotor (widening of blood vessels resulting from the relaxation of the muscular wall of vessels) effects the human skin, and is induced by vibration of low-amplitude (10–25 μm) and high-frequency (150–250 Hz) (Skoglund, 2008).

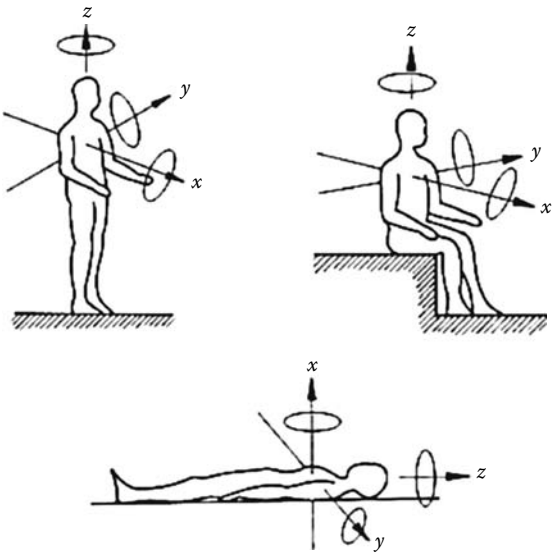
The human response to vibration depends on the part of the body which is exposed. There are two broad types of vibration to which workers are exposed: vibration transmitted to the whole body (WBV) (Bovenzi and Betta, 1994); and vibration applied to a part of the body, known as segmental-vibration. Segmental-vibration is due to the contact of body parts with vibrating controls or machine parts. WBVs are the most common form of vehicular vibration. Vibration enter the body through the buttocks and feet, and to a lesser extent the hands. This may cause risks to the health and safety of workers, in particular lower-back morbidity and trauma of the spine (Wolcott, 2001). Scarlett et al. (2007) reported that on International Organization for Standardization (ISO) test track WBV levels increased in proportion with forward speed, irrespective of the suspension system provided to the test vehicles. Hand–arm vibrations (HAVs) are caused by vibration transmission into the hand and arms through the palm and fingers when operator uses power tools and vehicle controlling systems. This may lead to risks affecting the health and safety of workers, in particular bone or joint, neurological or muscular disorders. Regular exposure to HAV may damage the tissues of the hands and arms.

13.4.1 Mechanical Vibration

Vibration, be it sinusoidal or random, whole-body or segmental, occurs in one or more directional planes. On the basis of direction of action, mechanical vibrations which affect the human body can be grouped into two types: rectilinear and rotational or angular (ISO standard 2631: 1985). Rectilinear vibrations are transmitted to the human body in an orthogonal coordinate system viz. vertical, longitudinal, and transverse (Figure 13.2). In this system, three components of vibrations, a_z, a_x, and a_y, are considered. Almost all tractors during field operations are subjected to these three directional vibrations (Matthews, 1966). The angular vibration can be yaw, roll, and pitch. The rotational mode of vibration does not usually cause much discomfort. However, when tractors go over a rough terrain, the pitching or rolling motions of the seat may be more disturbing than rectilinear vibrations (Griffin et al., 1982). Limited information is available on the effects of angular vibrations on human body (ISO standard 2631-1: 1985).

13.4.2 Measurement of Vibrations

Accelerometers can be used for the measurement of mechanical vibrations. But there is a basic difference in the vibration exposure of the operator. The tractor driver experiences WBVs, while power-tiller operators experience segmental vibrations, mostly at the hands, which are further transmitted to the chest through the arms. For tractors, measurements should be made at two locations: one on the cab floor, close to the seat mounting point, and the other on the driver's seat approximately below the driver's ischial tuberosities, vertically below the seat index point. For power-tillers, measurements should be made at the front and/or top of the engine, the end of the handle of the power-tiller and on the hand, shoulder, and chest of the operator as it involves segmental vibration. WBV measuring equipment should comply with the ISO 8041 (2005) specifications. The basic instrumentation consists of a transducer (accelerometer), an amplifying device and a data logger



Rectilinear vibrations	Rotational vibration
x-axis Longitudinal	θx - Roll
y-axis Lateral (Transverse)	θy - Pitch
z-axis Vertical	θz - Yaw

FIGURE 13.2
Coordinate system for mechanical vibrations influencing the human body. (From ISO 2631-1:1985, *Evaluation of Human Exposure to Whole-Body Vibration, Part 1: General Requirements*, withdrawn on 1997-05-01 is reproduced with permission of the International Organization for Standardization, ISO. ISO Standards can be obtained from any ISO member and from the Web site of ISO Central Secretariat at the following address: www.iso.org. Copyright remains with ISO. With permission.)

and display. Figure 13.3 shows a general schematic diagram for instrumentation and data transfer. Accelerometers are used to convert mechanical energy into electrical signals. The accelerometers are calibrated by using a gap sensor. This electrical signal is a function of mechanical vibration. Various types of accelerometers are available, but not all are three directional. Most accelerometers have good sensitivity, reasonable cost, a wide frequency range, are small in size and light in weight and thus are capable of measuring vibrations at a specific point without loading the vibrating structure. Figure 13.4 shows a schematic of accelerometer calibration.

13.4.3 Computation of Vibration

Vibration describes actual motion associated with a source. The magnitude of vibration is the frequency-weighted acceleration value in the highest of three orthogonal axes, that is, *X*-axis, *Y*-axis, and *Z*-axis for a seated or standing worker (EN 14253: 2003; ISO 2631-1: 1997).

13.4.3.1 Vibration Frequency and Frequency Weighting

For WBV, the frequencies thought to be important range from 0.5 to 80 Hz, whereas for HAV, it would be 8 to 1000 Hz (EU Good Practice Guide WBV, 2006). Because the risk of

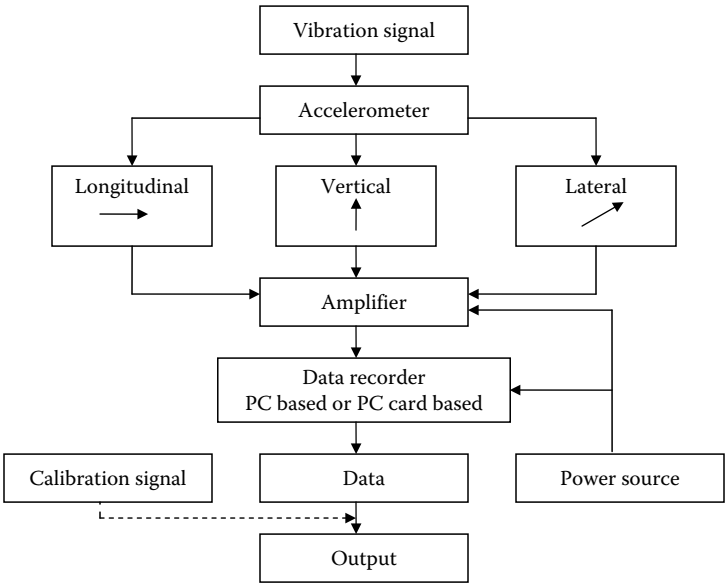


FIGURE 13.3
Schematic diagram of instrumentation for vibration measurement.

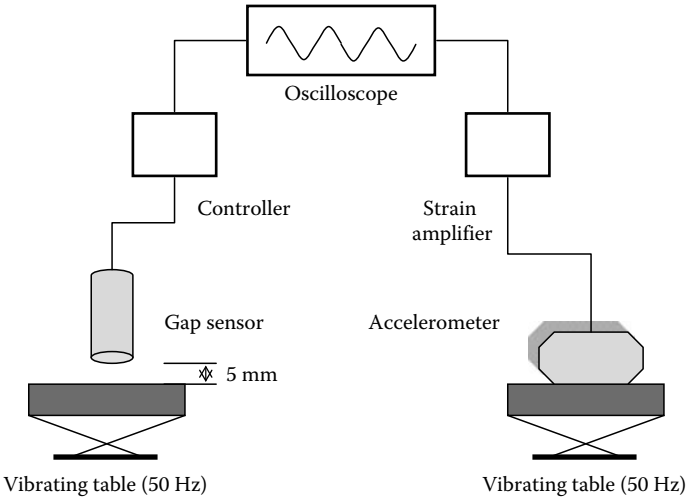


FIGURE 13.4
A schematic of accelerometer calibration by using gap sensor.

damage is not equal at all frequencies, a frequency weighting is used to represent the likelihood of damage from the different frequencies. As a result, the weighted acceleration decreases when the frequency increases. While considering the risks to health from WBV an additional multiplying factor must be applied to the frequency-weighted vibration values. For the two lateral axes (x and y), the acceleration values are multiplied by 1.4 and for the vertical, z-axis vibration the factor is 1.0 (ISO 2631-1: 1997) (Table 13.2).

TABLE 13.2

Frequency Weightings and Multiplying Factors for (WBV) Specified by ISO 2631-1:1997 for Seated Person

Measurement Axis	Frequency Weighting	Multiplying Factor (*k*)
Longitudinal (*X*) axis	Wd	1.4
Transverse (*Y*) axis	Wd	1.4
Vertical (*Z*) axis	Wk	1

Source: ISO: Standard 2631-1, *Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole-Body Vibration—Part 1: General Requirements*. International Organization for Standardization, Geneva, 1997.

So WBV emission level, evaluated in terms of frequency-weighted root-mean-square (r.m.s.) acceleration (A_w) in m/s^2 is given by the equation:

$$A_w = \left[\frac{1}{T}\int_0^T a_w^2(t)\mathrm{d}t\right]^{1/2} \ldots \tag{13.1}$$

where

$a_w(t)$ is the frequency-weighted acceleration time history (m/s^2)

T is the duration of measurement (s)

Where vibration exposure consists of two or more periods of exposure to different magnitudes and durations, the (frequency-weighted) energy-equivalent acceleration (A_{eq}) corresponding to the total duration of exposure may be derived. This is effectively an overall average r.m.s. acceleration for the total period in a specific direction:

$$A_{eq} = k\left[\frac{\sum a_{wi}^2 T_i}{\sum T_i}\right]^{1/2} \ldots \tag{13.2}$$

where

A_{eq} is the axis-weighted energy-equivalent continuous acceleration (r.m.s.) acceleration (m/s^2)

a_{wi} is the vibration magnitude (r.m.s. acceleration [m/s^2]) for exposure period T_i

$\sum T_i$ is the total duration of exposure/measurement

k is the orthogonal axis multiplying factor specified by ISO 2631-1: 1997 (see Table 13.2)

13.4.3.2 Determination of Daily Vibration Magnitude

The European Physical Agents (Vibration) Directive (EU PA(V)D, 2008) has proposed two alternative methods of vibration exposure assessment.

1. Eight hour energy-equivalent ($A(8)$) frequency-weighted, continuous r.m.s. acceleration over an 8 h period.

The vibration exposure levels are evaluated individually from the acceleration time histories recorded in each of three orthogonal axes following application of the

frequency-weightings and axis-weighting factors ($1.4a_{wx}$, $1.4a_{wy}$, or a_{wz}). The highest value of the three is the daily vibration exposure value. Daily vibration exposure level ($A(8)$) (unit: m/s^2), expressed as 8 h energy equivalent continuous, frequency-weighted r.m.s. acceleration is ($A(8)$) given by

$$A_w(8) = A_{eq}\sqrt{\frac{T}{8}}\ldots \tag{13.3}$$

where T is the daily exposure period (h).

The vector sum of these three directional acceleration values is used in assessment of exposure, that is, the vibration total value, which is a combination of three a_{hv} values for the axes x, y, and z, given by (ISO 5349-1: 2001):

$$A_{hv} = \sqrt{\left(\left(a_{hvx}\right)^2 + \left(a_{hvy}\right)^2 + \left(a_{hvz}\right)^2\right)} \tag{13.4}$$

where

a_{hvx}, a_{hvy}, and a_{hvz} are the frequency-weighted r.m.s. acceleration values for x, y, and z direction (m/s^2)

a_{hv} is the vector-sum vibration magnitude (m/s^2)

The vector-sum vibration magnitude, which represents the overall vibration in three orthogonal directions, is used to calculate the 8 h energy equivalent, root-sum-of-squares (RSS) frequency-weighted total r.m.s. acceleration value ($A(8)$):

$$A_H(8) = A_{hv}\sqrt{\frac{T}{8}} \tag{13.5}$$

where

T is the duration of exposure period to the vibration magnitude (h)

$A_H(8)$ is the 8 h energy equivalent, RSS frequency-weighted total r.m.s. acceleration value (m/s^2)

2. Vibration dose value (VDV) of the frequency-weighted acceleration

The VDV provides an alternative measure of vibration exposure. The unit for VDV is meters per second to the power 1.75 (m/s$^{1.75}$). The VDV gives a better indication of the risks from vibrations that include shocks as, unlike the r.m.s vibration magnitude, the measured VDV is cumulative value, and that is, it increases with measurement time. Table 13.3 shows the "exposure action" (EAV) and "exposure limit" values (ELV) for WBV and HAV, both in 8 h energy equivalent r.m.s. acceleration and in VDV.

13.5 Practical Implication for Vibration Exposure Assessment

It is obvious that workers are often unable to understand the scientific methods of determination and assessment of vibration exposure. So, to make the task easier for

TABLE 13.3

Vibration Exposure Values Specified by the EU PA(V)D for WBV and HAV Computed by *A*(8) and VDV Methods

		8 h Energy Equivalent r.m.s. Acceleration *A*(8) (m/s^2)	VDV (m/s$^{1.75}$)
WBV	EAV	0.5	9.1
	ELV	1.15	21
HAV	EAV	2.5	—
	ELV	5.0	—

Source: EU PA(V)D. 2008. European Physical Agents (Vibration) Directive. http://www.humanvibration.com/EU/VIBGUIDE/ (accessed January 12, 2008).

the understanding by the layman ISO has suggested some approximate indications of perceived comfort level, discussed next.

13.5.1 ISO Indications for Likely Perception of Discomfort Resulting from WBV

ISO 2631-1:1997 suggests approximate indications of public perception to a range of the overall total (RSS–r.m.s.) vibration emission values. Table 13.4 shows likely perception of discomfort resulting from WBVs.

13.5.1.1 Daily Vibration Exposure Graph

This gives a simple alternative method for daily exposures or partial vibration exposures without the need of a calculator. If we know the frequency-weighted vibration magnitude and the exposure period of an operator, the daily vibration exposure graph helps us to judge the safety of working condition (EU PA(V)D, 2008).

13.5.1.2 Daily Exposure Nomogram

The nomogram is another simple alternative method for obtaining daily vibration exposures, without using any equations. It consists of three scales; the left-hand line for weighted

TABLE 13.4

Likely Perception of Discomfort Resulting from WBV

Vibration Total Value (m/s^2)	Perceived Comfort Level
Less than 0.315	Not uncomfortable
0.315–0.63	A little uncomfortable
0.5–1.0	Fairly uncomfortable
0.8–1.6	Uncomfortable
1.25–2.5	Very uncomfortable
Greater than 2.0	Extremely uncomfortable

Source: ISO: Standard 2631-1, *Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole-Body Vibration—Part 1: General Requirements*. International Organization for Standardization, Geneva, 1997.

TABLE 13.5

Exposure Score Corresponding to the EAV and ELV for HAV and WBV

	HAV	WBV
EAV (2.5 m/s^2)	100	100
ELV (5 m/s^2)	400	529

acceleration (left scale for x- and y-axes values and right scale for z-axis values), central line for partial vibration exposure (8 h energy equivalent) and right-hand line for daily exposure time. For more details, refer to EU PA(V)D (2008).

13.5.1.3 Exposure Point System

Vibration exposure management, either hand–arm or whole-body, can be simplified by using an exposure points system. For any working process, the number of exposure points accumulated in 1 h can be obtained by using empirical equations. Exposure points are simply added together, so one can set a maximum number of exposure points for any person in one day, and by comparing that number with the given table of exposure points. The daily vibration exposure value is determined (Table 13.5).

13.6 Standard ISO Procedure for Tractor WBV Measurement

The ISO has provided the standard procedure for the measurement of mechanical vibrations experienced by operators while driving farm machinery (ISO Standard 5008: 2002). The recommended forward speeds for test with 100 m (smoother) and 35 m (rougher) tracks are given in Table 13.6.

In countries like Croatia, as high as 13% of the total occupational diseases are caused by hand-transmitted vibrations (HTVs) (Goglia et al., 2003). Such hazards, including peripheral vascular, neurological, and musculoskeletal disorders, are commonly referred by the term "hand–arm vibration syndrome" (HAVS). The ISO 5349-1 (2001) have recommended measurement of r.m.s. frequency-weighted acceleration to describe the magnitude of the vibration transmitted to the driver's hands. Acceleration values from one-third octave band analysis can be used to obtain the frequency-weighted acceleration a_{hw}:

TABLE 13.6

Recommended ISO Tractor Forward Speeds to be Used on ISO Ride Vibration Test Tracks and the Dimensions of Test Track Strips

		Dimensions of Concrete Strips of Track (mm)		
Test Track	Tractor Forward Speed (km/h)	Width	Length	Height
ISO 35 m (rougher)	4, 5, 7	80	500	5–285
ISO 100 m (smoother)	10, 12, 14	80	500	5–285

$$a_{\mathrm{hw}} = \sqrt{\left[\sum_{j=1}^{n} (W_j a_{\mathrm{w},j})^2\right]} \tag{13.6}$$

where

$a_{w,j}$ is the acceleration measured in the jth one-third octave band (m/s^2)

W_j is the weighting factor for the jth one-third octave band

The value of the weighting factor can be obtained from Table 13.7.

ISO 8727 (1997) suggests measurement of vibration accelerations in three directions (Figure 13.5) of an orthogonal coordinate system. The orientation of the coordinate system

TABLE 13.7

Weighting Factors Relative to the Frequency Range of Maximum Acceleration Sensitivity for the Response Curves of Figures 13.3 and 13.4

	Weighting Factor	
Frequency (Hz)	**Longitudinal**	**Transverse**
1	0.5	1
1.25	0.56	1
1.6	0.63	1
2	0.71	1
2.5	0.8	0.8
3.15	0.9	0.63
4	1	0.5
5	1	0.4
6.3	1	0.315
8	1	0.25
10	0.8	0.2
12.5	0.63	0.16
16	0.5	0.125
20	0.4	0.1
25	0.315	0.08
31.5	0.25	0.063
40	0.2	0.05
50	0.16	0.04
63	0.125	0.0315
80	0.1	0.025

Sources: Adapted from ISO: Standard 2631-1, *Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole-Body Vibration—Part 1: General Requirements*. International Organization for Standardization, Geneva, 1997; DOSH, *Guidelines on Occupational Vibrations*, Department of Occupational Safety and Health Ministry of Human Resources, Malaysia, 2003. Available online at http: //dosh.mohr.gov.my/koperat/G-PANDUAN%20PDF/GUIDE-Vibration.pdf. With permission.

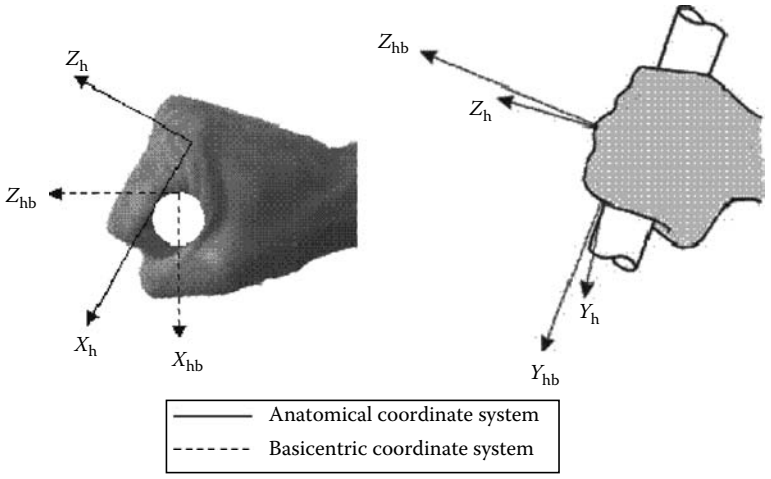


FIGURE 13.5
Coordinate system for measurement of vibration accelerations at hand. (Figure not to scale.) (Redrawn after Goglia, V. et al., *Appl. Eng.*, 34, 45, 2003.)

can be defined in accordance to an appropriate basicentric coordinate system originating in the vibrating handle or steering wheel gripped by the hand. Basicentric coordinates are relative to objects in contact with the body, and approximates the biodynamic coordinates and are more practical to measure since vibration sensors are mounted on the vibrating object rather than on the person. In the whole-body basicentric coordinate system, the critical axis is the *z*-axis, and it is parallel to the spine.

13.7 Human Responses to Vibration

It has been widely recognized for a number of decades that WBV as well as HAV are major sources of discomfort for agricultural tractor and power-tiller operators during typical farm operations (Matthews, 1966; Bovenzi and Betta, 1994; Lines et al., 1995). Exposure of people to vibrations may result in biological, physiological, and psychological effects (Liljedahl et al., 1989). The overall vibration transmitted to a human body in contact with the machine is made up of different frequencies of vibration occurring simultaneously. This is an important fact to consider when measuring human vibration since the human body is not equally sensitive to all frequencies of vibration (Sam and Kathirvel, 2006).

Bèkèsy (1939) investigated the transmissibility of vibrations through the human body (Figure 13.6). He found that frequencies up to 6 Hz are transmitted through the body without any change or reduction. While vibrations with frequencies greater than 6 Hz are not transmitted to the upper part of the body, as frequencies above 6 Hz exceed the resonance range of lower body parts and are thus filtered out. Only frequencies above 20 Hz are able to reach the heart. The knee will be reached by frequencies with 35–50 Hz. Moreover he stated that the situation for a seated person is not significantly changed, as the higher frequencies are then absorbed by seat instead of legs. In spite of all these investigations, the human organs which are susceptible to vibration cannot be exactly figured out or located.

When tissues of the body are exposed to sources of vibration corresponding to their natural frequency these tissues go into resonance. The natural frequency of a human body

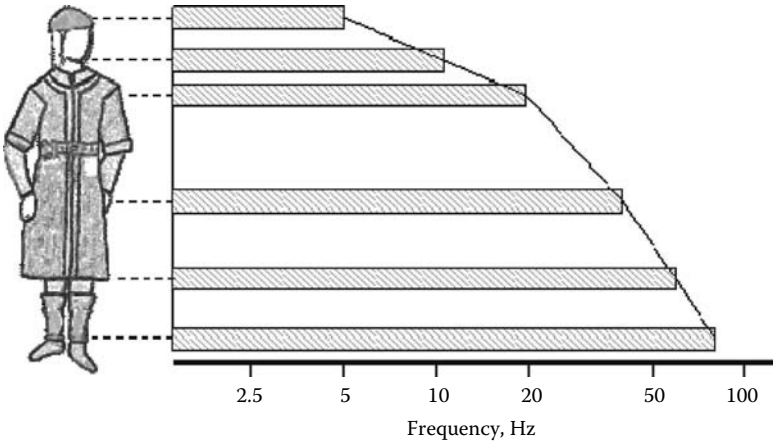


FIGURE 13.6
Transmissibility of vibrations through human body in standing position for different frequencies. (Figure not to scale.) (Redrawn after Bèkèsy, G. V., *Akust. Z.*, 4, 360, 1939.)

TABLE 13.8

Natural (Resonance) Frequencies of Different Body Parts for Mechanical Vibration in the Vertical Direction

Body Part	Natural Frequency (Hz)	Ref.
Head	20–30	Dieckmann (1968)
Body	4–6	Dieckmann (1968)
Body	4–6	Guignard and Irwin (1960)
Heart	4–6	Coreman (1960)
Heart	4–6	Dupuis and Christ (1966)
Stomach	4–5	Dupuis and Christ (1966)
Entrails	3–7	Dieckmann (1968)
Hand–arm system	5	Coreman (1960)
Spine	3.4–4	Dupuis and Christ (1966)

in seating position was found to be in between 4 and 6 Hz (Guignard and Irving, 1960; Dieckmann, 1968). There are many more resonances in the body, and the resonance frequencies vary among people, and with posture. Table 13.8 shows the natural (resonance) frequencies of different body parts for mechanical vibration in the vertical direction obtained in different studies.

13.7.1 Effects of Vibration on the Human Operator

There are number of studies related to the effects of mechanical vibration on the health of drivers, on highways as well as off-road. Mechanical vibrations have short-term as well as long-term effects on the human body. The National Institute of Miners' Health, Nagpur, conducted vibration surveys in various mines of India. It was found that operators of heavy earth-moving machinery were at greater health risk from exposure to vibration than other machine operators. A similar study conducted on farmers in North India reported that

TABLE 13.9

Vibration Source in Various Industries

Industry	Type of Vibration	Common Source of Vibration
Agriculture	Whole body	Tractors, backhoes
Construction	Whole body	Heavy equipment vehicles, e.g., bulldozers, graders, and excavators
	Hand–arm	Pneumatic tools, jackhammers, jackleg, stoppers, and vibrating concrete breakers
Electrical	Hand–arm	Hilte guns, drills, and saws
Foundries	Hand–arm	Air compressed grinders, discs, rotaries, and jitterbugs
Iron and steel	Hand–arm	Impact wrenches and grinders
Machine tool	Hand–arm	Impact wrenches and grinders
Mining	Whole body	Jumbo drills, dumpers, dozers, shovels, and backhoes
	Hand–arm	Rock drills and grinders
Riveters	Hand–arm	Rivet guns and impact wrenches
Transport	Whole body	Buses, trains, helicopters, jeeps, trucks, motorcycles, and motorboats
	Hand-arm	

regular work-related backache was more common among tractor-driving farmers (40%) than nontractor-driving farmers (18%) (Kumar et al., 2001). Mandal and Srivastava (2006) tabulated source of vibrations in various industries (Table 13.9).

13.7.1.1 Low-Back Pain

Several epidemiological studies of long-term exposure to WBV have shown damage to the lumbar spine with musculoskeletal disorders in the back (Fishbein and Salter, 1950; Rosegger and Rosegger, 1960; Dupuis and Christ, 1966; Bovenzi, 1996). At maximum acceleration levels, frequencies near the resonant frequency of the body (4–5 Hz) cause high mechanical forces leading to disk failure (Seidel et al., 1980; Wilder et al., 1994). In a survey of work-related injury risk for farmers Allen et al. (1995) found that about 41% of the respondents reported spinal cord injury as their main disability. Epidemiological studies conducted by NIOSH (1997) showed a higher prevalence rate of low-back pain, herniated disk, and early degeneration of the spine in WBV exposed groups. In a study investigating the prevalence of low-back disorders in agricultural tractor drivers exposed to WBV and postural stress in Northern Italy, Bovenzi and Betta (1994) compared various tractors in different farm operations. These comparative results are presented in Table 13.10.

13.7.1.2 Neck and Shoulder Pain

HAVs occurring while driving power-tillers and tractors are the main source of vibration resulting in neck and shoulder disorders and sometimes head pain. The symptoms, which include effects on peripheral circulation, the peripheral nerves or the musculoskeletal system, have also been recognized as a serious occupational disease (Gemne et al., 1995). Daily exposure to HAVs over a number of years may cause permanent physical damage known as "white finger syndrome." It can also damage the joints and muscles of the wrist and the elbow (Reynolds and Keith, 1977; Sam and Kathirvel, 2006). Since this disease

TABLE 13.10

Comparative Values of Vibrations at Different Farm Operations[a]

Tractor	Number of Vehicles Tested	Vector Sum of Frequency-Weighted Acceleration (m/s² r.m.s.)[b]
Fiat (50–70 hp)	14	1.24 ± 0.34
Ford (45–60 hp)	23	0.96 ± 0.39
Fendt (58–64 hp)	9	0.89 ± 0.25
International (58 hp)	2	1.08 ± 0.31
Lamborghini (65–80 hp)	2	1.05 ± 0.27
Massey Ferguson (50–85 hp)	3	1.41 ± 0.51

[a] Vector sum of the frequency-weighted rms acceleration recorded on the seat pan of several types of tractors while ploughing, mowing and fertilizer spreading.
[b] Mean ± standard deviation.

causes a vascular disorder it is more likely to occur in cold weather (Mishoe and Suggs, 1977). Balasankari and Salokhe (1999) conducted a survey in Coimbatore district, Tamil Nadu, India to determine tractor utilization and the human–machine interaction during tractor operations. They reported that 61% of the respondent tractor drivers expressed shoulder pain after tractor driving. About 75% of the young farmers expressed shoulder pain, as they were very new to the profession and were not used to driving for a long period. Neck and knee pain were also common problems with all tractor drivers.

13.7.1.3 Other Health Problems due to Vibration Exposure

The study conducted by Rosegger and Rosegger (1960) showed that 76% of tractor drivers were affected by stomach complaints. A survey in East Germany reported that more than three-quarters of tractor drivers are affected by stomach disorders, and a large number suffered gastritis (Haack, 1965). Hip and buttock pains are commonly suffered by tractor operators involved in prolonged driving. During the last few decades a number of studies showed that farmers suffer from an increased risk of hip joint arthrosis, with a tenfold increased risk found in some studies (Torèn et al., 2002). Drivers of vehicles subjected to low-frequency bounce vibrations risk developing motion sickness (Reason, 1978). Prolonged exposure to WBV at frequencies below 20 Hz results in hyperventilation and increased heart rate, oxygen intake, pulmonary ventilation, and respiratory rate.

13.7.2 Effects of Vibration on Performance

Tractor operating demands the adoption of a very unhealthy posture. Sometimes nearly half of the energy of driver is spent in bracing himself against the seat and dampening out jerks (Bjerninger, 1966). Improper posture could result in musculoskeletal problems and sick leave among tractor operators (Greysten and Sjögren, 1996). Visual performance is generally impaired due to vibration in the frequency range from 10 to 25 Hz (Sanders and McCormick, 1987). Walking behind the power-tiller controlling its operation is tedious work which imposes a great workload on the operator resulting in fatigue. Muzammil et al. (2004) found that vibrations generated during tractor driving, and the use of tractor-operated farm equipment, have significant effects on the operator. Low-frequency tractor ride vibrations may result in driver discomfort and the possibility of spinal injury (Baker, 1994).

13.8 Methods for Attenuating the Vibration

Low-frequency tractor ride vibration, resulting in driver discomfort and the possibility of spinal injury, became a recognized issue during the 1960s. Analysis of vibration is complex, especially for off-road conditions, as the vibration is dependent on operating speed, surface condition, wheel inflation pressure, tire stiffness, and provision of suspension for seat, cab, and axle. Thus, for attenuating the vibration levels one has to consider these factors and modification of them will eventually attenuate the vibration.

13.8.1 Suspension Systems

The suspension system is used to reduce the shocks and jerks experienced due to a rough terrain. There are four main areas which are considered in suspension design: the tires, frames, cabs, and seats. Shock absorption in automobiles is performed by a system that carries the weight of the vehicle while attempting to reduce or eliminate vibrations generated by wind forces, braking forces, and road irregularities (De Temmerman et al., 2004a,b; Bouazara et al., 2006). In general, there are three types of suspension: passive suspension, active suspension, and semiactive suspension (Karnopp, 1978; Wu and Griffin, 1997; McManus et al., 2002; Bouazara et al., 2006).

13.8.1.1 Seat Suspension

Modern tractors tend to have good seat suspension, at least in the vertical plane. The tires of the tractor act as the main means of suspension but the extent to which they provide protection varies considerably (EEC, 1978; Ashby and Parker, 2004). Janeway (1975) showed vibrations in the vertical direction are predominant while working with wheeled-tractors, whereas the effect of longitudinal and transverse modes of vibration is highly dependent upon the type of work being performed by the vehicle (Stayner et al., 1984; Scarlett et al., 2007). Thus, most of the work in this regard has been focused only on attenuation of vibration in the vertical direction. Less effort has been spent in the reduction of lateral and longitudinal vibrations.

Much work has been done on the design of tractor seats, seat cushions, backrests, and on provision of suspension system. The most widely used passive seat suspensions are not very effective in reduction of vibration. On the other hand the use of an active suspension system is difficult due to its complexity and high cost. Thus, many researchers are working on semiactive suspension systems featuring electrorheological (ER) and magentorheological (MR) suspension (Wereley and Pang, 1997; Choi et al., 2000; McManus et al., 2002; Choi and Han, 2007). But these methods are currently suited only for road vehicles; hence research has to be extended to use these suspension systems for tractors.

A seat on a power-tiller tractor will minimize the arduous energy demand occurring from the need to walk behind the machine while holding the handles (Karmakar, 1997). Tewari et al. (2004) modified a hand tractor to enable operation in a seated position which resulted in considerable reduction of the human energy consumption in all operating conditions. In a research study with a four-wheel drive, 19 kW Kubota tractor, Kiattisak (2004) investigated the feasibility of seat vibration attenuation by incorporating a damper in the seat suspension system. Vibrations were measured in three directions—longitudinal (pitching), lateral (rolling), and vertical (bouncing)—by installing transducers at the seat and seat base. Two operators of 68 and 89 kg were employed—as between 55 and 98 kg

FIGURE 13.7
New seat suspension system with pneumatic damper. (From Kiattisak, S., Development of a seat suspension system for a small four wheel tractor. Masters thesis no. AE-04-6, Asian Institute of Technology, Thailand (Unpublished), 2004.)

is considered as the typical range applicable to Asian conditions (ISO 5008, 2002). New seat suspension consisted of two coiled springs and adjustable pneumatic damper (Figure 13.7). The newly designed seat showed promising results in the frequency range from 2 to 8 Hz. With damping constants (*c*) 1177.7; 716.5; 695.5; 334.7; 69.4 Ns/m and spring constant (*k*) 14,343 N/m, the new seat facilitated the operators' ability to work as long as 8 h. Compared to the existing seat, it significantly reduced vibration along vertical direction. It also offered postural comfort to the operators' abdomen, shoulder, hip, low back, and upper back.

Often, tires are the only suspension elements on most agricultural tractors in developing countries. The suspension characteristics of tires, with the masses and geometry of tractor, largely determine the ride vibration characteristics over rough surfaces. Teerawat (2007) conducted research on the influence of tire inflation pressure and surface conditions on tire's spring stiffness (*k*) and its damping coefficient (*c*), and on the WBVs transmitted to the operator. He tested two tractors (19 and 25 kW) with five inflation pressures, three forward speeds, and three operating conditions—standard rough track (ISO 5008), soil, and asphalt surfaces. In the drop test it was observed that tire inflation pressure had a significant influence on tire spring stiffness and its damping coefficient values. The former increased with tire inflation pressure, whereas the latter decreased. Similarly, surface conditions also altered the tire spring stiffness and its damping coefficient values obtained in drop test.

Tire inflation pressure did not alter WBVs in the longitudinal and lateral directions. In contrast, inflation pressure showed a significant effect on the WBV in the vertical direction where it increased with the inflation pressure. The level of WBV reduced when the tractors were operated on the standard rougher track, soil, and asphalt surface conditions, respectively. Tractor forward speed significantly affected WBV in the three orthogonal axes as WBV increased with speed. The level of WBV successively reduced when the tractors were operated on standard rougher track, soil, and asphalt surface conditions, respectively.

On the standard rougher track with the given range of tire pressure, vibration values at the operator's seat revealed the potential risk on operator health for exposures of 2.5 h duration. The exposure time could be increased by reducing forward speed. In field operations on a soil surface with the higher tire pressure, the vibration values at the seat showed the potential risk for exposure of 2.5–4 h duration. This exposure time could be increased by reducing tire inflation pressure or tractor forward speed. In transportation mode on an asphalt surface under all tire pressure conditions, the vibration values at the seat suggested a harmless effect on operator health for exposures of 8 h.

13.8.1.2 Vehicle Cab Suspension

Along with the seat, the cab floor of a tractor is also a major source of mechanical vibration transmission to the operator. A suspension system placed between the wheels and the rest of the vehicle offers a higher potential to decrease vibration levels (Hilton and Moran, 1975). The cab suspension is capable of isolating the driver not only from terrain-induced vibrations but also from forces introduced due to implement loads (Prasad et al., 1995). Figure 13.8 shows a schematic of tractor cab suspension. Hansson (2002) optimized the cab suspension of an agricultural tractor by an algorithm to optimize the vertical and horizontal suspension parameters. He found that suspension with nonlinear damping element is better than one with a linear damping element. Ahmed and Goupillon (1997) developed an analytical model for prediction of ride vibration of a tractor. Deprez et al. (2005a,b) modeled a hydropneumatic element that can serve as part of a cabin suspension. They used the global optimizer DIRECT to optimize the VDV and frequency response function for three measured terrains. De Temmerman et al. (2004a,b) formulated a linear model of a conceptual cab suspension.

13.8.1.3 Vehicle Axle Suspension

If suspension is provided at both axles then it is called a "Fully suspended" vehicle. Marsili et al. (2002) installed an independent, electronically controlled active suspension on the

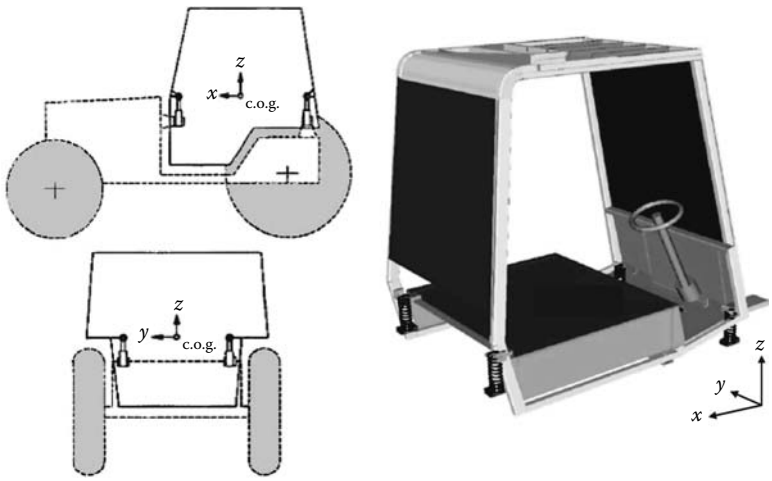


FIGURE 13.8
Schematic of cab suspension system with spring and damper arrangement. (Left: Redrawn after Hansson, P., *Biosyst. Eng.*, 81(1), 57, 2002.) (Right: Redrawn after Lemerle et al., 2002.)

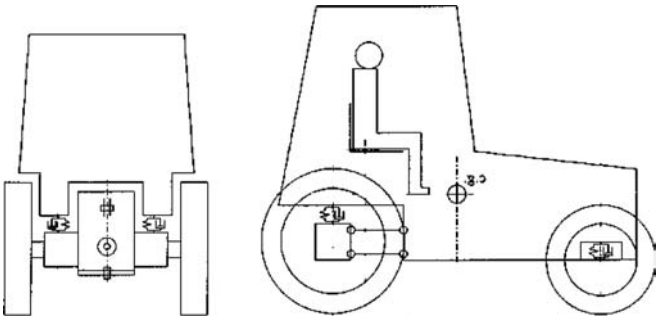


FIGURE 13.9
Schematic view of tractor with front and rear axle suspension. (Redrawn after Hansson, P., *Biosyst. Eng.*, 81(1), 57, 2002.)

front axle of a tractor. They found an average decrease in acceleration in the test without and with an implement as 13% and 15%, respectively. According to Claar et al. (1980) desirable features of axle suspension system are: reduction of the loads transmitted directly to the chassis structure; that the seat does not required a large relative movement between the seat and the operator controls; and that the suspension ought not to impart a sense of insecurity to the operator as might a cab suspension. Hansson (2002) reported that if the vehicle is supplied with both front and rear axle suspensions with normal seat position, the front axle suspension mainly influences the longitudinal and pitch vibrations. Figure 13.9 shows front and rear axle suspension system with a typical spring-damper arrangement.

13.8.1.3.1 Three-Point Linkage Dynamic Control

Tractors are often driven with heavy trailed mounted or semimounted implements. The vibrations are transferred from the implement to the tractor chassis via the three-point linkage. Experimental and analytical investigations have shown that suspensions and the coupling systems for the rear implement, modify the vibration behavior of the tractor and can have a great influence on steering and drive safety (Ulrich, 1983). The combination of the front axle suspension and the three-point linkage shock absorber often involves a higher reduction in vibration (Marsili et al., 2002).

13.8.1.3.2 Tire Characteristics and Loading Conditions

The technical characteristics of a tire, such as number of lugs, lug average area, sculpturing ratio, lug height, and static wheel stiffness have important effects on the accelerations measured both on the tractor rear axle and on the driving seat (Servadio et al., 2007). But, these tire characteristics are dependent on several factors like inflation pressure and tire temperature as well as driving velocity. Kising and Göhlich (1989) stated that considerable decrease in damping can be observed by increasing speed, and slight decrease with increasing inflation pressure. Lowering tire pressures reduces vibration due to the reduction in tire stiffness and the fact that the tire sidewalls act as shock absorbers. Vibrations experienced due to empty trailer attachment are perceived to be greater than for a loaded trailer (Balasankari and Salokhe, 1999). Teerawat (2007) stated that the tire pressure does not have any significant effect on longitudinal and transverse vibrations, but vertical vibrations have good correlation with tire pressure.

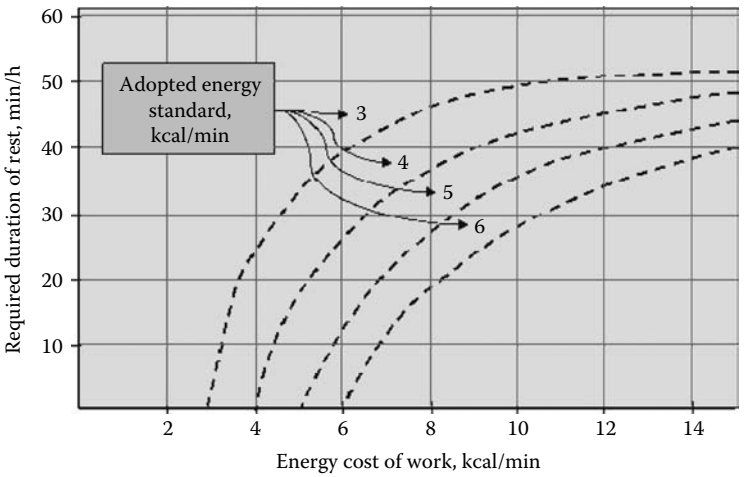


FIGURE 13.10
Total rest requirements for work activities of varying energy costs for energy expenditure standards (ceilings) or 3, 4, 5, and 6 kcal/min; a generally accepted standard is 4 kcal/min. the rest requirements for maintenance of the adopted standard are given per hour (left) and per 8 h day (right). (Redrawn after Murrell, K.F.H., *Human Performance in Industry*, Reinhold Publishing Corporation, New York, 1965.)

13.8.2 Reduction in Exposure Time

Continuous working for an allowable exposure time may affect operators directly or indirectly. The resting periods are necessary to recover the lost energy. The total time required for rest can be calculated by using following formula or by using a graph of rest required per hour or per 8 h shift (Murrell, 1965).

$$R = \frac{T(K-S)}{(K-1.5)} \ldots \tag{13.7}$$

where

R is the rest required (min)

T is the total working time (min)

K is the average kcal/min of work

S is the standard kcal/min, adapted

The graph (Figure 13.10) is helpful for determining the total rest time during an operation, if the energy requirement for work is known in kcal/min. The graph gives the rest time for an hour and also for usual daily work of 8 h.

13.9 Vibration Studies on Power-Tiller

Power-tillers (mostly known as walking tractors or hand tractors) are popular, especially in developing counties, for both dry and wetland operations. Power-tillers are mostly

adapted for rice cultivation because of their compact size, light weight, suitability for small plots, ease of maintenance, and comparatively low price. During the past few decades there has been a steady increase in the use of power-tillers in Southeast Asian agriculture. Most of the farmers in this region are poor and farm sizes are small. In this situation, power-tillers have become an attractive economic and operational alternative for farmers (Salokhe et al., 1995). Use of power-tillers reduces the human–land ratio while increasing the output–labor ratio (Kathirvel et al., 1991). Versatility of the power-tiller is another reason for its extensive use in field operations. The power-tiller can be used to operate the typical cultivation implements used in agriculture such as a moldboard plough or disk plough. But power-tillers are not exempted from mechanical vibrations; power-tiller operators have to endure various environmental stresses which reduce their overall performance. Mechanical vibration is one of the most important causes for reduced efficiency and impaired performance of operators.

During field operations, the operator must guide the machine by walking behind it. Thus the walking control-type hand tractor imposes a greater workload on the operator and results in fatigue. HTV of such a tractor is very strong since the handle grip of a walking tractor is a cantilever beam, and the power is obtained from a single cylinder diesel engine (Ying et al., 1998). Operators of hand tractors are exposed to a high level of vibration arising from the dynamic interactions between the tool and workpiece. Sometimes a power-tiller is used for transportation, in which case it is provided with an operator's seat. This seat should provide a better ride with control and adequate safety (Tewari et al., 2004). A seat on the hand tractor minimizes the strenuous energy demand arising from the need to walk behind the machine while holding the handles and guiding it forward. A major portion of energy (80%–85%) is spent in walking behind the machine depending on soil conditions (Karmakar, 1997). But some power-tiller manufacturers do not make provisions for a seating arrangement due to the instability of the machines during waterlogged wetland field operation.

Both walking-control and riding-control type power-tillers are widely used at present. In the case of walking-control type tillers, vibrations are transmitted through the hands to the operator's body (HAV) whereas, in the case of riding control-type tiller, vibrations are transmitted though hands as well as seat (HAV and WBV). Measurement and analysis of the characteristics and intensities of mechanical vibration of power-tillers during common farm operations is essential, to provide a better ergonomics working environment for the operator. But analysis of power-tiller vibration is complex, as acceleration and frequency of vibration changes depending on engine speed and terrain conditions (Majumder, 1994). Excessive vibration and noise levels are the important shortcomings in power-tiller design (Pawar, 1978). About 5%–7% of the total human energy is wasted due to vibration and noise while operating a power-tiller (Singh and Kaul, 1972). The unevenness of the road is also a source of excitation of the HTVs, and the unevenness of the road makes up about 20% of the total HTV of the walking tractor (Jiao et al., 1993).

Majumder (1994) studied the vibration characteristics of Thailand-made power-tillers in a stationary condition, and during transportation and tillage. He recorded vibration intensities at the operator's chest during off-road and on-road transportation, and first and second tillage in the field. During off-road transportation, the maximum acceleration and frequency of vibrations at the operator's chest were 1.01 m/s^2 and 14.46 Hz, respectively, at 1800 rpm engine speed in the vertical direction. During on-road transportation, these were increased to 1.14 m/s^2 and 20.12 Hz, respectively. Irrespective of the engine speed and the mode of operation, maximum acceleration was observed in the vertical direction and lowest acceleration was in the lateral direction. The frequency of vibration was higher in

the vertical direction for all engine speeds and all modes of operation, but the frequencies in longitudinal and lateral directions were found to be similar at a given engine speed for a particular mode of operation. In any mode of operation, increase in engine speed results an increase in the acceleration and frequency of vibration in all three directions. Figures 13.11 and 13.12 reveal typical results of vibration intensities and frequencies during first tillage (first plowing straight laps) at the operator's chest.

Mamansari (1998) presented an ergonomics evaluation of a commonly used power-tiller in Thailand. The vibration characteristics of the power-tiller over different surfaces (viz., concrete, asphalt, grass, and soil) in stationary, transportation, and field-operating modes, were analyzed. Among all sites where vibration was measured on the power-tiller, significantly higher vibration levels were observed at the tip of the handle which has direct contact with the operator's hands. The vibration level of the power-tillers increased with an increase in engine speed in the stationary and transport modes, and vertical vibration was significantly higher than the longitudinal and lateral vibrations. Dominant frequencies and corresponding accelerations at different locations of the power-tiller under stationary conditions are presented in Figure 13.13 (Majumder, 1994).

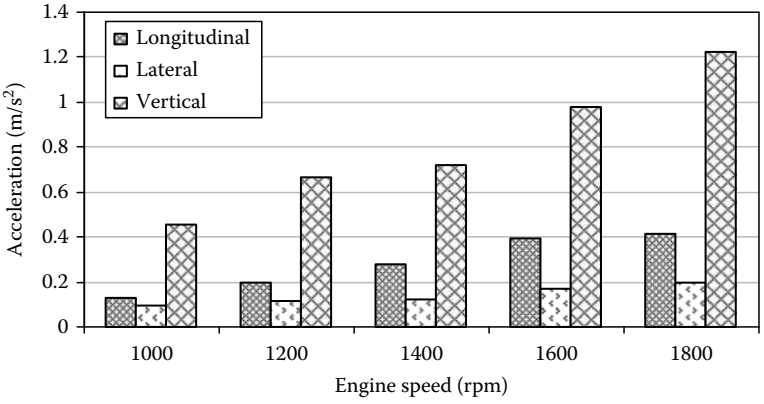


FIGURE 13.11
Vibration acceleration at operator's chest observed for first tillage.

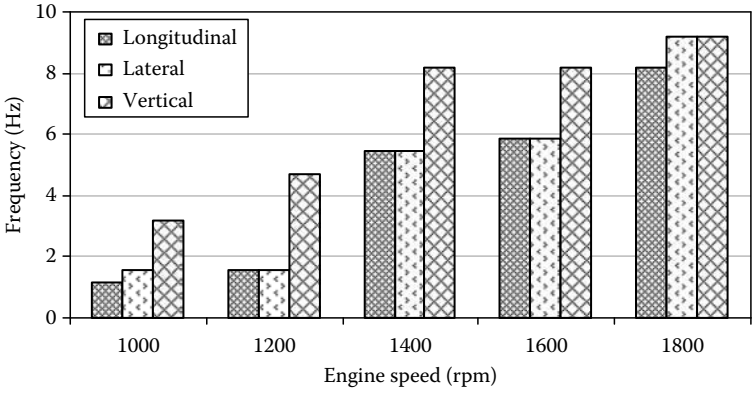


FIGURE 13.12
Vibration frequency at operator's chest observed for first tillage.

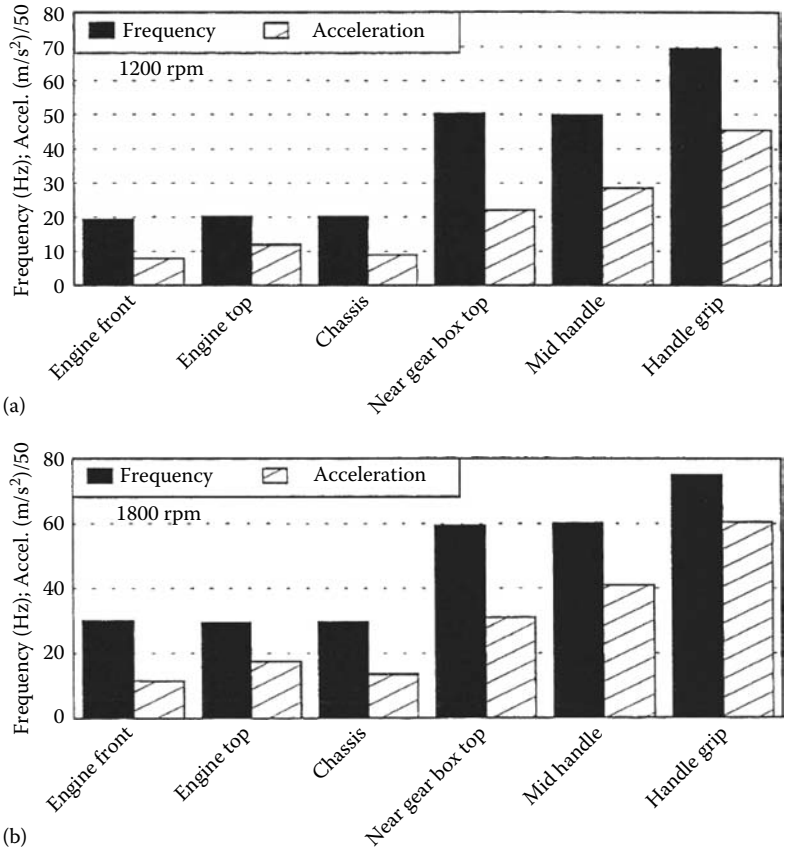


FIGURE 13.13
Most dominant frequencies and corresponding accelerations at different locations of power-tiller at stationary conditions. (From Majumder, B., Vibration and noise characteristics of a Thai-made power-tiller. Masters thesis no. AE-94-4, Asian Institute of Technology, Bangkok, Thailand (Unpublished), 1994.)

Sookkumnerd (2000) analyzed the effect of a vibration isolator to reduce the vibration of the walking tractor with cage wheels and pneumatic tires as wheel assembly. Experiments were carried out with a walking tractor performing different agricultural operations. As expected, a pneumatic tire wheel assembly showed lower vibration acceleration than did cage wheels, due to the damping effect created by the rubber material of pneumatic tires. The value of r.m.s. acceleration was increased when machine was used with an implement.

Presence of moisture in the soil reduced the vibration acceleration during first and second plowing as compared to the dryland operation, as the soil became soft due to being wet. However, second plowing showed reduced levels of vibrations compared to the first plowing for a given engine speed and surface condition. Figure 13.14 compares the r.m.s. acceleration at the handle tip at 2000 rpm engine speed for different operating conditions. Using natural rubber blocks as vibration isolators beneath the engine reduced the r.m.s. acceleration at higher engine speeds. The elastic properties of the isolator material have a significant influence on the vibration isolation. Upon lowering the spring constant the isolation region began at lower engine speeds. During plowing operations in

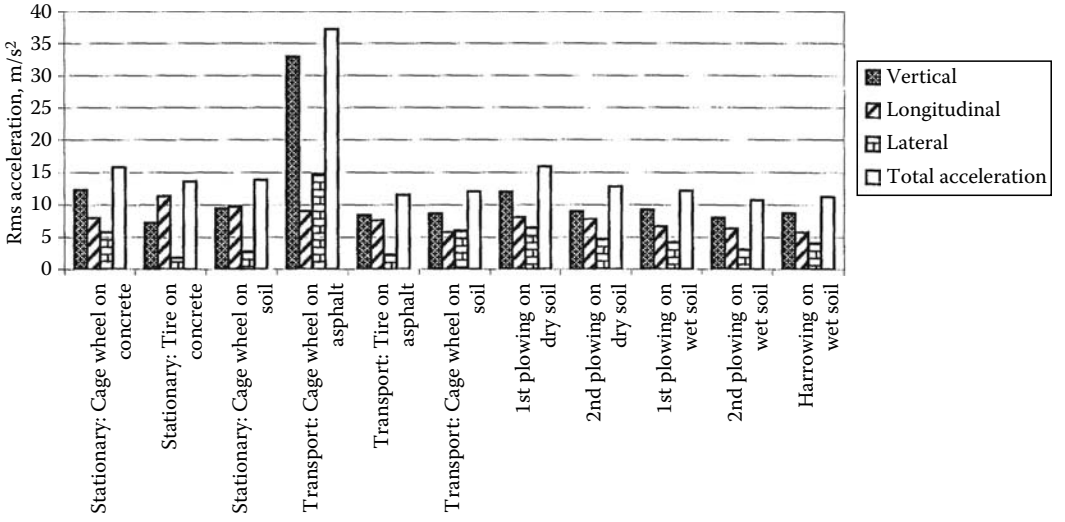


FIGURE 13.14
Comparison of rms acceleration at the tip of the handle at 2000 rpm engine speed in different operating conditions. (From Sookkumnerd, C., Investigations into walking tractor vibrations. Masters thesis AE-00-2, Asian Institute of Technology, Bangkok, Thailand (Unpublished), 2000.)

wetland conditions the vibration level of the conventional walking tractor exceeded the ISO standard for 2.5 h fatigue-decreased proficiency limit. With the vibration isolator, this limit was increased to 4 h fatigue-decreased proficiency limit.

Higher vibration acceleration occurs in the vertical direction, and vibration levels in all three directions increase as engine speed increases. Provision of a seat on a power-tiller reduces HTVs (Tewari et al., 2004; Sam and Kathirvel, 2006). Rubber isolators can reduce the vibration when the engine is operated, but only in the isolation region. Tewari et al. (2004) modified a hand tractor to enable operation in a seated position. They observed that vibration intensity in r.m.s. acceleration was at maximum of 45 m/s^2 without the seat, whereas this value was 20 m/s^2 with the seating arrangement.

13.10 Conclusions

The most valuable resource in any country is its people. Most of the world's population, especially in developing countries, is still involved in agriculture or agriculture-based activities as their main occupation. The mechanization and modernization of these occupations have increased enormously, which helps in increasing efficiency and production but at the same time affects workers' health. Thus, to maintain the safety and health of the people developments are reexamined on the basis of ergonomics. In developed countries considerable efforts have been made to provide safe and healthy environments to the farming community. However, no such systematic effort is available in the Asian region and hence there is a need for a more systematic study.

Farmers have to deal with the vibrations and noise caused by tractors and power-tillers. The logical method of reducing ride vibration levels of any vehicle is to introduce one or

more suspension systems between the vehicle vibration source and the operator. Most agricultural tractors in developing countries are equipped with only passive seat suspension to reduce the vibrations transmitted to the driver, which is not efficient. Thus, other methods of vibration attenuation, like cab suspension, axle suspension, and three-point-linkage dynamic control have to be adopted. Several studies reveal that vibrations in the vertical direction are higher in magnitude. Hence most of the focus has been on the attenuation of vibration in vertical direction, and much less effort has been made in the reduction of lateral and longitudinal vibrations. Besides passive suspension methods more attention has to be given to active and semiactive methods. The ER and MR suspensions which are currently practiced for on-road cars have to be modified for off-road use.

Along with the scientific study of the effect of vibrations on the human body and vibration attenuations, generating awareness among the people, mainly in the farming community, is equally important. Operators should know the effect of vibration on the body and should take appropriate rests while working, as well as other appropriate precautions. In order to do this they have to be provided with enough information and facilities. The knowledge thus acquired through this study could be utilized to improve the present status of tractor design with suitable suspension systems for the isolation of the operators from harmful vibrations.

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14

The Contribution of Ergonomics to the Forestry Industry in Developing Countries

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14.1 Introduction

It is universally acknowledged that work in the forestry industry is physically demanding with diverse natural and material hazards all contributing to an industry with an exceptionally high injury occurrence. This is evident even in highly industrialized countries

such as Sweden, Australia, New Zealand, and Canada. Of concern is that there are very few accurate statistics of injuries and fatalities in the forestry industry in the developing nations such as Chile and more so in South Africa.

To a greater or lesser degree, in the forestry industry globally, there are two important aspects of work in which ergonomics input can make useful contributions. The first, and the one most pertinent to developing countries, is heavy manual labor. Research worldwide has demonstrated the high energy demands of all aspects of manual work in the forestry industry leading to a depletion of nutrition stores, increased body temperature, dehydration, and ultimately fatigue leading to injuries and often fatal errors. The opposite side of the spectrum is represented by mechanized work where human energy is replaced by machines, and workers become progressively more sedentary in often highly monotonous and repetitive work. Despite this mechanization the industry is still fraught with injuries and fatalities suggesting that ergonomics input has not been successful in alleviating the problems associated with work in this industry. It is the authors' contention that in order to ensure that ergonomics makes meaningful and lasting contributions, the application needs to be specific to the country involved. Although this chapter will identify the challenges faced in the forestry industry in the developing countries of Chile and South Africa specifically, it also contends that any country undertaking ergonomics research in this type of work needs to consider more than just the work itself, and should include aspects such as the socioeconomic status of the workers, their health, and nutritional status as well as cultural and political contexts, to name a few.

Worldwide forestry work is characterized as physically demanding manual labor, with extreme natural and material hazards from differing sources which all contribute to the high risk of injury to forest workers (Golsse and Rickards, 1990; Driscoll et al., 1995). Forest harvesting is particularly hazardous, being associated with between 38% and 90% of all accidents in the industry (ILO, 1991; Manyuchi et al., 2003). Although falling trees and handheld machinery are recognized as increasing the risk of injury, it has been argued for over 20 years that fatigue and injuries in forestry are predominantly due to the tremendous biomechanical and physiological loads associated with the job requirements (Kukkonen-Harjula and Rauramaa, 1984; Gaskin, 1990; Parker et al., 1999; Manyuchi et al., 2003). Within forestry high physical workloads combined with natural hazards have been blamed for the elevated accident and injury occurrence. In Sweden it is reported that there are 13.6 fatalities per 100,000 workers per year in forest harvesting (Thelin, 2002); a major concern is that in contrast to other industries within Sweden, trends indicate that fatalities are on the increase within forestry in that country. Other developed nations reveal even more alarming statistics; New Zealand figures suggest 121 deaths per 100,000 workers per year (Feyer et al., 2000) while Australia had 396 deaths per 100,000 workers per year (Driscoll et al., 1995). Unfortunately reliable statistics are not available in most developing countries where accidents and consequential injuries are likely to be substantially higher.

McLean (1996) explained that another contributor to poor work practices has been the restructuring of forest harvesting to contractors which was initiated in New Zealand in the late 1980s and which is currently in operation in South Africa and Chile, i.e., the allocation of fieldwork to contractors. The introduction of competitive independent contracting has, according to McLean (1996), resulted in poor labor practices. Thelin (2002) reported a similar practice in Sweden and explains that this may be the reason why forest harvesting is one of the only industries in Sweden with an upward trend in injury statistics. An article by Tam et al. (2003) writing on the behavior of contractors generally, and in the construction industry specifically, has identified four areas of major concern, these being the lack of providing and maintaining appropriate tools, lack of adequate training, no continuous

supervision, and poor control and overall organization. These and other studies contend that contractors are seldom members of an occupational health care system from which education and information about work risks are obtainable. Limited economic and technical resources also contribute to the lack of training, as do long working days without rest and recovery.

14.2 The Chilean Forest Industry

14.2.1 General Information

Due to the Chilean geography, climate, and availability of natural forests, Chile has a long tradition as a producer and exporter of wood and other products derived from wood. In the past, Chile was covered with forests in a considerable extent of its land. The distribution of climatic conditions, from dry in the northern part to cold in the extreme south, with an important reserve of soils under temperate climate, favored the development of forests. Chile has a total area of 75 million hectares. The land suited for forestry reaches 33.8 million hectares, which is equivalent to 45% of the surface of the country. It is important to highlight that in the past, forest production was linked to the exploitation of natural forests, but in the last 50 years the whole process was reversed toward the utilization of plantation forests of foreign species introduced into the country. For example in 1940, 70% of the volume of wood was harvested from natural forests, and in 1974 this had diminished to 25%, and at present it is below 10%. Therefore, more than 90% of current wood production in Chile comes from plantations, which are generally radiata pine and eucalyptus.

14.2.2 Employment in Chilean Forestry

After the legal decree passed in 1974, the increment of the surface planted with different species has been possible mainly because of the active participation of forestry enterprises. The evolution of forest resources has been accompanied by an equivalent industrial growth meaning that there is an active participation of the forestry sector in the national economy. After copper mining, the forestry industry is the most important source of income for the country. The noticeable growth of the forest sector has significantly contributed to the generation of labor. The challenge is to increase the quality of products and to optimize productive processes in order to maintain a presence in the international market, which is highly competitive. These, and social reasons, make forestry laborers more and more important. It is estimated that the forest industry employs nearly 130,000 workers. From this total, around 40,000 workers are occupied in forest activities. With respect to the whole country, the forest sector provides around 2.5% of employment, of the total labor force of around 5.9 million workers. Historically, this figure is in agreement with the statistics available and the reader should take it as a global view of the contribution of the forestry sector to the generation of work. It is important when discussing employment in forestry to point out that the growth of the forestry sector gave origin to large forestry companies. These companies have outsourced a lot of their operations to contractors, the aim being to increase productivity as contractors would be more specialized and efficient. Unfortunately this has not been the case and the working and living conditions of the laborers are often very poor. In summary, it can be said that in the past laborers employed by contractors lived in poor conditions in forest camps, had insufficient food given their

hard labor, and that the safety conditions were poor and their earnings very low. Although such situations still exist, as they do in South Africa, stricter control is being enforced in Chile, and ergonomics studies have shown noticeable improvements in both living and working conditions.

14.3 The South African Forest Industry

14.3.1 General Information

South African forestry is divided into the three major components of commercial forestry (plantation forestry), conservation forestry, and community forestry (Tewari, 2001). Commercial forestry, also referred to as plantation or industrial forestry, is divided into the three broad categories of silviculture, harvesting, and processing. The commercial forestry industry is the second largest cultivator of land in South Africa and has a capital base of R30 billion and an annual turnover of R12 billion (Tewari, 2001). It meets 95% of the country's needs in wood-based products and has a positive trade balance of R2 billion per annum. The forestry industry is one of the strongest forces in creating rural employment with more than 200,000 people benefiting directly from employment, or indirectly by income-generating opportunities (Tewari, 2001). Forestry contributes 7.3% to the gross value of agricultural output and forestry plantations, on more than 1.5 million hectares, cover the second largest land area of grown crops, following maize (4 million hectares) in South Africa. This is of particular interest as, unlike Chile, South Africa is not a natural forest-rich country with most of its indigenous forests concentrated on the eastern coast in the provinces of Mpumalanga and Kwazulu-Natal.

14.3.2 Stakeholders in Commercial Forestry

Although there are numerous stakeholders within the industry, Tewari (2001) noted that the two main ones are management and the field workers. He also indicated that during the apartheid regime power was concentrated with white management and commercial farmers, the black manual workers were largely disempowered. The main focus at that time was on economic growth of the industry rather than on sustainable development. In the postapartheid era however, there has been a rapidly changing face of commercial forestry in South Africa with the commercial forestry companies having experienced a gradual weakening of their power and influence (Tewari, 2001). The secondary stakeholders in the industry have therefore increased considerably to include people and the environment beyond the industry itself. What is of major concern is that no single group has emerged to take power, and assume responsibility and accountability, previously exercised by the larger forestry corporations (Tewari, 2001). As a result, the best interests of the workers are not necessarily a priority in South Africa's forestry industry.

Another change in the postapartheid era has been the introduction of contracting, where the responsibility of work output and hence workers, has shifted from the major companies to smaller contracting companies. According to McLean (1996) the introduction of competitive independent contracting has resulted in poor labor practices in the forestry industry around the world. Even in Sweden, which has a technologically advanced harvesting sector, there has been an upward trend in injury statistics since the introduction of contracting (Thelin, 2002). Manyuchi et al. (2003) argued that in South Africa, since the outsourcing of forestry plantations to contractors, the excessive physical demands

being placed on the manual workers are being further exacerbated by these poor labor practices. Approximately 23,000 people are estimated to be employed by contractors in the country, and Manyuchi et al. (2003) purport that this has resulted in employing workers who lack the necessary skills. There is also failure to adhere to acceptable operating standards, the payment of low wages and job insecurity. To address these problems, the South African Forestry Contractors Association (SAFCA) was established which uses a grading system reflecting the quality of work of each contractor. However, the efficacy of this system is not clear. What is disturbing is the employment of workers who lack the necessary skills; this tends to be a common practice in industrially developing countries where unemployment and minimal education predominate (Scott and Charteris, 2004). The reality is that the nature of forestry harvesting work is physically demanding which is exacerbated by these negative influencing variables, and is an ergonomics issue which requires rigorous research.

14.4 Ergonomics in Chile and South Africa

With all the universally acknowledged problems associated with the forestry industry, ergonomics research is ongoing in developed countries. However, the applicability of their findings to developing countries such as South Africa and Chile is problematic due to the idiosyncratic nature of all work sites. It is imperative for the outcome of any ergonomics project, if it is to be of benefit to local workers, that the research is conducted within the different regions of a particular country and on the indigenous work force in the specific region.

14.4.1 Ergonomics Interventions in Chile

In 1968, Professor Nils Lundgren, a renowned Swedish medical doctor and ergonomist, visited Chile as a WHO consultant in ergonomics. After Professor Lundgren left the country, a team was organized to continue his pioneering work. The studies performed in the first years were devoted to the understanding of the physical characteristics of forestry workers, their social and working environment, and to the quantification of food intake and habits in relation to the energy expenditure of forest activities. An effort was also made to improve simple manual work methods with the aim to reduce workload and to increase efficiency. However, these were not the only aspects influencing manual work. The following section is divided into four parts and is a synthesis of ergonomics studies carried out in Chilean forestry, extracted from different publications (Apud et al., 1989, 1999; Apud and Valdés, 1995; Apud and Meyer, 2004). The first is a description of the characteristics of forest workers. The second is devoted to living conditions, while the third summarizes some case studies carried out in silvicultural treatments and harvesting. As the Chilean forest industry continues to grow, the presence of machines is increasing and becoming one of the most important sources of ergonomicically related problems affecting the worker. Mechanization is therefore discussed in the final part.

14.4.1.1 The Chilean Forest Workers

Before tools and working methods could be matched to workers, the first step was to know their physical aptitudes. The most important finding was that the average "fitness" of this population was very good, in part because of natural selection and in part because of the

physical conditioning inherent in their job. The studies also indicated that Chilean forestry workers tend to be smaller than workers in other sectors of Chilean society and significantly smaller than forestry workers in northern Europe, North America, and other industrialized countries producing forest machinery. Body composition, an important indicator of energy balance, was also investigated and the results revealed that fat mass in this population indicated sufficient dietary energy intake and musculoskeletal development for body size and capacity to respond to the effort required. Although the workers' physical "fitness" was good, productivity was low. One possible hypothesis was that low salaries discouraged workers from applying themselves. Although this was clearly an important factor, field observations indicated that this was not the only determinant. Therefore, the analysis was then focused on the work and living environment.

14.4.1.2 The Living Environment

The geographical characteristics of Chile make forestry work an isolated job, carried out far from urban centers. Most forestry workers are housed in camps which constitute a home away from home. In ergonomics, the usual concept is to apply ergonomic criteria to the job itself, but we believe it is unreasonable to expect forestry workers to be motivated, no matter how well organized their work is, if their living conditions are poor. We looked for answers primarily in terms of the camp infrastructure and camp food. Living conditions in forestry camps were extremely poor. For example, a study undertaken in 1980 by the Directorate of Labor found that 41 of 42 forestry camps evaluated failed to meet minimum standards of hygiene and comfort. The camps in question belonged to contractors servicing larger enterprises. Since then, a serious attempt has been made to improve camp infrastructure and maintenance while some of the larger enterprises have funded studies for the design of prototypes and now directly handle the camp contract, which requires contractors to ensure good maintenance. Although many problems persist, it is fair to acknowledge that progress is being made and that camps are progressively being replaced by better facilities.

Another initial concern was to examine the diet of Chilean forestry workers. It was found that the diet varied significantly from one contracting firm to the next. Energy consumption ranged from a daily average of 11,721–14,651 kJ (2,800–3,500 kcal), with much variation among the different types of workers. For example, power-saw crews/chainsaw operators generally consumed more than less-skilled workers. The same studies showed that the diet was made up primarily of carbohydrates, and consumption of fruit, vegetables, and animal proteins was quite low, and in addition there was a marked vitamin A deficiency. With this knowledge in mind, the main problem was to relate food intake to production. During a study conducted to learn about the physical fitness of the workers, it was noted that a contractor had characterized his workers as being "productive workers" and "average workers." A review over a period of six months revealed that the so-called productive workers could do, on average, about 25% more work than the other workers. Interestingly, they also had average intakes of about 2093 kJ (500 kcal) which was more than the average workers. It was the only significant difference between the groups. In fact, their body mass, stature, fat mass, fat-free mass, and aerobic capacities were very similar. Those workers lived at home so they were not all receiving the same diet. As in any family, the amount of food available for the group depends on its size, earnings, and other factors.

Another study investigated energy balance in a group of 57 workers. The laborers stayed 9 h in the forest although they only worked five of those hours. Their other daily activities were very sedentary. In Table 14.1 a summary is presented of the estimated energy

TABLE 14.1

Mean Energy Expenditure Values of 57 Forestry Workers during Work, Outside of Work and for the Whole Day

		Energy Expenditure	
Activity	**Hours**	**kcal**	**kJ**
During work	9	2,324	9,728
Physical work	5	1,950	8,163
Rest breaks	4	374	1,566
Outside work	15	1,217	5,095
Recreation	7	697	2,918
Sleep	8	520	2,177
Total	24	3,541	14,823

expenditure of this group for the different periods of the day. As can be seen, these workers expended more energy during 5 h of actual work than during the remaining 19 h. Together with the study of energy expenditure a survey of energy intake was carried out on the sample of 57 subjects. The average energy intake was found to be 14,731 kJ (3,519 kcal) which, when compared to daily expenditure, showed that these subjects had a reasonably good energy balance. That was also confirmed when analyzing their body weight in relation to stature and fat mass content. Their average mass was 65 kg for a mean stature of 1660 mm and their body fat was 14.1%. In the face of this evidence, some of the big forestry enterprises financed studies aimed at improving forestry workers' diets, in terms of both quality and energy intake. However, it was not easy to find a solution that also fulfilled the conditions laid down by these enterprises, i.e., affordable diets which would be easy to prepare under camp conditions.

The question that arose even before analysis of the dietary composition, was what energy intake forestry workers need. Further studies led to the conclusion that most forestry activities would require a daily supply of at least 16,744 kJ (4,000 kcal). However, this is only a very general figure as the environmental setting, the actual workload and specific individual traits produce a wide range of requirements. In an attempt to design a menu, a study was carried out on a group of workers living in a camp. Although the meals were still rich in carbohydrates, they also included sufficient vegetables, fruit, and animal protein to exceed the minimum recommendations of the Joint FAD/WHO Committee of Experts on Nutrition. Evaluations carried out in 2001 did show a net improvement in the diet of the workers in the camps. Around 80% of the contractors have adopted diets similar to those originally proposed.

14.4.2 Ergonomic Studies of Labor-Intensive Methods

Before describing some examples of the applied ergonomics research carried out in Chile, it is important to mention that we have tried to adhere to the standard performance criteria defined as the output which skilled workers can produce without excessive work in an average working day. This was based on the assumption that they know and accept the working method and are motivated to apply it (International Labor Organization, 2000). The studies on appropriate technologies were done on control crews who operated just like any other group of workers but who had everything they needed to do the job correctly. During the working periods they lived in comfortable, clean camps, and had

adequate supplies of food prepared by a carefully trained cook. The camp also had basic recreational facilities such as television, playing cards, and so forth. The control crews were well trained for their specific tasks and basic work safety standards were also met.

Another concern, and this also has to do with the International Labour Organization's (ILOs) definition of standard output, was the criteria for determining excessive workloads. Therefore, techniques were implemented to evaluate energy expenditure and to quantify cardiovascular load (Apud et al., 1989). In general, studies have focused on specific forestry production and management jobs. Following are some brief summaries of studies conducted on pruning to analyze two different working techniques, plus a harvesting study as an example of teamwork.

14.4.2.1 Pruning Techniques

Until recently, the traditional high-pruning method in Chile was to use a saw with a 6 m handle. The worker cuts the branches from the ground at quite a distance from the pruning area, a method which is bound to produce a source of flaws. Moreover, the job requires the neck to be held in a very awkward extended position and the shoulders and arms to be exposed to a heavy static load as they work overhead. One alternative is to use pruning ladders, bringing the worker closer to the job. This aids and improves cutting while reducing work-posture problems. There is a higher risk of accidents, for example, falling from the ladder, but these can be avoided with proper safety measures. A control crew of 10 tree trimmers was used to make a comparative evaluation of the two systems of work. The two stands were very similar, as were climate and terrain. The physical load for each worker was estimated by measuring heart rate (cardiac frequency) once every 2 min throughout the day. In Chile, heavy labor is defined as that which raises the heart rate above a daily average of 115 beats per minute in young workers. The findings showed that tree trimmers using a ladder to prune could trim an average of 125 trees per working day, whereas a worker on the ground covered only 96 trees per working day. In both instances, the average heart rate throughout the day was a highly comparable 100 beats per minute, quite acceptable for an 8 h working day. More importantly, the figure was no higher with the more productive method, even though tree trimmers had to climb up and down the ladder. This was because pruning from the ground required constant movement to maneuver into a position where the branches could be seen, and another contributing factor was that they were working with a tool held above their head. The pruning from a ladder also produced a much better quality cut. The workers mentioned that they did not experience arm or leg fatigue, while neck and shoulder complaints were fewer. In conclusion, the ladder method has been recommended and many forestry enterprises have now adopted it as their method of choice.

14.4.2.2 Forest Harvesting As an Example of Teamwork

During the Final Cut the workers are organized in such a way that a power-saw operator fells the trees and three axe workers debranch them. A choker setter then takes the logs to a cable crane for aerial transport. When investigated, this work was carried out over two days. Afterwards, the same workers went to the log yard where the trees, previously moved with the help of oxen, were cross-cut by the same power-saw operator and piled by the axe workers. The work in the log yard lasted one to one and a half days. After the field study, a new work organization was proposed because there was a clear imbalance between the demands imposed on the workers making up the crew. The problem started with the power-saw operator who could not fell more trees because the axe workers were

debranching at a very high work rate and therefore it was not possible for them to debranch more logs. As a consequence it was proposed to increase the number of axe workers to four. At the same time, considering the expected increment in production, it was also recommended to include a second choker setter, as the individual choker setter was also working with a high cardiovascular load. With respect to the manual piling of logs, it was recommended that this task should be eradicated from the forest. Therefore, piling and the previous ox skidding was replaced by a machine (triloader). With the addition of two assistants needed in the log yard, the crew increased from 7 to 12 workers, showing that, with this kind of technology, mechanization does not necessarily mean reduction in the number of workers. It has to be pointed out that with this new organization the work in the forest was carried out simultaneously to that in the log yard, and not on different days by the same workers as in the original organization.

The new organization included 15 min rest pauses at midmorning and midafternoon. During these scheduled rests, the workers were provided with a soft drink and fresh fruit. Both the rest and the snack were welcomed by the workers. Information provided by the contractor and by the large company confirmed that production increased from 700 to 1500 m^3 per month with the new form of work. Of course there was more investment and expenses, but the economic analysis showed good benefits. The fact that with the new organization the number of workers increased and a machine was introduced to the system, new incremental costs were produced, which were added to those already existing in the original work. These were considered in the economic evaluation of both systems. Although the contractor had to pay for the rent of the triloader, he had a real increment in earnings of 60%. Machine operators increased their salaries by 47%, power-saw operators by 19%, and axe workers by 1.5%.

In conclusion, these summarized studies highlight an important fact that it is possible to innovate successfully without big investments. However, to keep the positive changes in the long run, salaries have to be improved. After the study everybody was satisfied with the new system, except the axe workers who carry out the physically demanding job of debranching. Their salaries were kept about the same and not increased substantially as with the other categories of workers. When these problems are not appropriately solved, the workers affected will not keep the required work pace because of lack of motivation, and they will delay the whole process. Therefore the recommendation to the contractor was to increase the salaries of the axe workers.

14.4.2.3 Mechanization in Chilean Forestry: Present Problem and Future Challenges

The growth of the forest sector in Chile has been accompanied by an increment in mechanization. Although mechanized work is physically lighter it involves other risks for the machine operators. For example, those derived from the often static and unnatural working postures, the noise and vibrations produced by the machines and also a noticeable increment of the mental workload. For this reason, job rotation and scheduled rest breaks are also very important for the machine operator. The main problem is that when machines are not correctly built, it is easy to detect what is wrong, but is extremely difficult to modify the design, mainly because most of the modifications are very expensive and also because some of the required adaptations may produce other problems, leading to a vicious circle. In such cases "remedy can be worse than disease."

Foresters, administrators, and, in general, all those who plan the technological innovation should not only consider cost and output, but they should also consider basic concepts on the adaptation of the workers. The question is how to motivate the people who

make the decision to get the required knowledge. They have other duties and skills and a lack of knowledge of human adaptation to work. Therefore, by using checklists already published in the literature it was concluded that the real need was a checklist combining the headings of the elements to be verified and additionally, for each topic, give a written synthesis of simple and illustrated basic concepts to facilitate problem solving for the users. The challenge is to get the target groups to in fact start using them, which will take time and effort.

14.4.3 Ergonomics Interventions in South Africa

Ergonomics research in the forestry industry in South Africa is relatively new compared to that which has been done in Chile and as such, much of the research was based on the Chilean experiences. A comprehensive investigation of the labor-intensive jobs of forest harvesting (chainsaw operations, debarking, and stacking) started in 2002. Over 100 workers were assessed over a period of four years. The findings of these investigations and interventions are discussed.

14.4.4 South African Forestry Workers

Ergonomics evaluations tend to focus on the 8 or 12 h work shift and the responses of workers to task demands within the work setting. In developing nations however, it is important to take cognizance of the 24 h cycle of the workers (Scott, 1993) and the associated socioeconomic factors, considering that most of these laborers are from rural areas. The culmination of these elements is that many rural South African workers live on, or below, the breadline, and undernutrition or malnutrition are common. Although the negative consequences associated with these poor lifestyle factors on the work capacity of forestry laborers appear obvious, it has not generally been considered. Hence one aspect of the study initiated in 2002 was to obtain an information base regarding the workers likely to execute the required forestry tasks in order to provide some insight into their general condition.

Christie (2006) reported on the health status of chainsaw operators and stackers in her investigation. This research found that many workers had not been tested for many chronic diseases of lifestyle such as hypercholesterolemia or hypertension and some in fact, did not even know about the conditions. Christie (2006) therefore argued that the cardiovascular health status could not be accurately ascertained although previous research by Sparling et al. (1994) suggested a dose–response effect between increased physical activity levels in black South African workers by virtue of their work, which is predominantly manual in nature, and a reduced incidence of chronic diseases of lifestyle and coronary heart disease (CHD).

The results of a 24h dietary recall method of a sample of 59 chainsaw operators and stackers reported by Christie (2006) showed that the chainsaw operators were ingesting only 49% of the recommended daily allowance (RDA), while the stackers had higher energy consumption (5346 kJ), but were still only ingesting 67% of the RDA. These findings are in contrast to the Chilean forestry workers who had adequate dietary intakes. Protein and fat intake were marginally below the recommended level and although carbohydrate intake was sufficient for sedentary individuals, for workers involved in heavy manual labor, it was unacceptably low. Research on athletes suggests that in order to sustain dynamic exercise performance a consumption of 8 g of carbohydrate per kilogram body mass is necessary (Burke, 2002), which for a 65 kg individual is 520 g. The chainsaw operators and

stackers were ingesting only 110.9 and 186.8 g of carbohydrate, respectively, per day. These stores are not sufficient to sustain work performance for even a few hours and is a likely contributor to low work capacity. The findings emphasized the urgency of intervention for these workers particularly with regard to carbohydrate intake. It is well known that a depletion of carbohydrate stores in the form of liver and muscle glycogen is a precursor for fatigue (Goedecke et al., 1999). In fact, Loucks (2004) goes so far as to say that the limiting factor for physical performance is low energy intake, especially carbohydrate intake. O'Keefe et al. (1983) cautioned that undernourished black South Africans had a predominance of respiratory disease which would compromise work efficiency. Beside the deleterious effect on work efficiency these authors also reported on the strong association between undernourishment and increased susceptibility to infection and mortality.

In contrast, Biggs (2006) who investigated a group of forestry workers who received substantial weekly food rations in South Africa, found that the average energy consumption was 19,195 kJ which exceeds the recommended intake by 75%. Despite this, their diets were still deficient in vitamins A, B2, B12, C, selenium, and calcium. Biggs (2006) recommended that simple additions to the ration packs such as soya, beans, salt, sugar, maize meal, bread plus fruit, and vegetables would result in a more nutritionally balanced diet. The time at which the workers in the Biggs (2006) study ate was of more concern than the amount of energy consumed. A large portion of the workers (74%) ate for the first time during the day at the midmorning break. This resulted in low blood sugar levels and 10 of the workers (13%) starting work in a hypoglycemic state (blood sugar $<3.4\,\text{mmol}\,L^{-1}$). In addition, a survey carried out by James (2005) revealed that 16% of workers do not interrupt their tasks to eat at all during the shift. These workers tend to finish their tasks before having any nutritional intake, and this too can lead to a depletion of energy stores and the development of fatigue. Low blood sugar levels impair both cognitive and physical abilities and can cause a lapse of concentration, which would then increase the risk for accidents and injuries in an already hazardous work environment.

Despite limited statistical evidence the occurrence of musculoskeletal problems would arguably be greater in forest harvesting where manual work predominates, than in more mechanized operations. Furthermore, the lower worker capacity as a direct result of socioeconomic factors evident in South Africa, would likely exacerbate this negative scenario. Despite this, evidence points to a surprisingly low incidence of musculoskeletal disorders (MSDs) in South African workers (Renz, 2004) and specifically forestry workers (Manyuchi et al., 2003; Christie, 2006). Christie (2006) showed that the injuries reported by the chainsaw operators were primarily cuts on the lower extremities from the chain saw, or minor head injuries from falling branches. The stackers reported significantly lower overall incidence of injuries with only two workers reporting that they had sustained an injury in the previous 12 months. These were the result of dropping logs on the lower extremities. The supervisor argued that the very low reporting of problems was probably due to the workers' perceptions that they would be seen to be "complaining," and they feared for their jobs. This would be in agreement with the findings of Manyuchi et al. (2003) who reported that South African forestry workers did not report injuries or MSDs for fear of losing their jobs. As such, reliable statistics generally on South African workers' musculoskeletal health is severely lacking. This is despite the fact that it is well known that accurate reporting of work-related injuries assists in identifying unsafe areas and work practices, measures the impact of work-related problems on health, productivity, and costs, and prioritizes accident prevention measures and assesses the effects of safety improvements (Pransky et al., 1999). With respect to absenteeism, the predominant reason for missing work among the workers assessed in the South African research between 2002 and 2006 was toothache (Scott et al.,

2004; Christie, 2006). This interestingly was also the main reason for absenteeism amongst Chilean forestry workers (Apud and Valdés, 1995), which these authors attributed to poor diet, a factor which would also be feasible in the South African context.

14.4.5 Task Demands

14.4.5.1 Physiological Cost of Chainsaw Operations and Stacking

Table 14.2 shows the physiological responses of workers involved in chainsaw operations and stacking (Christie, 2006). As these workers work-to-task, each worker's shift was divided into four quarters. With respect to the chainsaw operators, heart rate, oxygen uptake, and energy cost remained stable during the first two quarters of their work shift,

TABLE 14.2

Energy Cost of Chainsaw Operations and Stacking for the Four Quarters of a Work Shift

	Time				
Variable	**First Quarter**	**Second Quarter**	**Third Quarter**	**Fourth Quarter**	**Entire Shift**
WHR (beats min^{-1})	120.7	118.9	125.8	127.4	123.3
	(11.1)	(12.5)	(12.5)	(13.3)	(10.8)
	117.6	119.66	116.89	117.12	117.64
	(11.4)	(15.23)	(15.30)	(12.95)	(12.95)
VO_2 (mL kg^{-1} min^{-1})	19.9	18.8	21.8	22.9	20.9
	(6.5)	(6.3)	(6.8)	(7.2)	(6.7)
	24.4	25.4	24.2	24.3	24.6
	(6.2)	(7.4)	(7.3)	(6.0)	(6.5)
VO_2 (L min^{-1})	1.32	1.24	1.43	1.51	1.38
	(0.43)	(0.41)	(0.43)	(0.47)	(0.39)
	1.61	1.68	1.58	1.60	1.59
	(0.43)	(0.52)	(0.50)	(0.41)	(0.42)
EE (kJ min^{-1})	26.4	24.9	28.8	30.3	27.6
	(8.6)	(8.2)	(8.6)	(9.4)	(8.6)
	32.4	33.8	31.9	32.1	32.6
	(8.6)	(10.5)	(10.0)	(8.2)	(9.1)
EE (kJ h^{-1})	1585.8	1494.7	1727.5	1818.9	1660.1
	(514.2)	(490.6)	518.1)	(563.8)	(469.4)
	1940.8	2025.9	1920.9	1924.1	1916.5
	(516.0)	(627.2)	(602.5)	(490.6)	(509.1)
EE (kcal min^{-1})	6.31	5.95	6.88	7.24	6.61
	(2.05)	(1.95)	(2.06)	(2.42)	(1.87)
	7.73	8.07	7.64	7.66	7.65
	(2.05)	(2.50)	(2.39)	(1.95)	(2.03)
MET	5.70	5.41	6.24	6.54	5.79
	(1.85)	(1.81)	(1.95)	(2.05)	(2.08)
	6.98	7.26	6.90	6.83	7.10
	(1.77)	(2.11)	(2.08)	(1.77)	(1.76)

Source: Taken from Christie, C.J., Physical workloads imposed on South African harvesters. Unpublished PhD thesis, Department of Human Kinetics and Ergonomics, Rhodes University, Grahamstown, South Africa, 2006.

Note: Shaded areas refer to the responses of the stackers.

WHR, working heart rate; VO_2: oxygen uptake; EE: energy expenditure; MET: metabolic equivalent.

i.e., when felling the trees. These responses then increased significantly when the workers changed to cross-cutting for the third and fourth quarters. This may be an indication of fatigue associated with "physiological drift," or could suggest that cross-cutting is more physiologically demanding than felling. During cross-cutting these workers followed a fairly indiscriminate pattern with a considerable portion of their task constituting walking over uneven terrain interspersed with forward bending to perform cross-cuts or debranching. Furthermore, increase in ambient temperature over the work shift is likely to have increased the physiological responses, as these workers started felling at day-break and once they were into the cross-cutting subtask they were exposed to hotter conditions. According to McArdle et al. (2001), any increase in temperature causes about a 5% higher oxygen uptake than in a thermoneutral environment, and is attributed to the thermogenic effect of elevated core temperature and the additional energy required for sweat gland activity and altered circulatory dynamics. In contrast however, the physiological responses of the stackers remained constant over time. This was an interesting finding considering that the stackers started working later than the chainsaw operators and were thus exposed to more heat stress later in the day. However, these workers may have developed means to counteract a progressive build up by varying the intensity of effort expended over the entire work period. The most extensive effort required was in the dragging and lifting to stack logs of up to 140 kg, while clearing a stacking patch took minimal effort.

The range of oxygen uptake and energy expenditure responses implies that, according to Sanders and McCormick (1993), "moderate-to-heavy" demands were placed on these workers. These responses were also very similar to those of Apud and Valdés (1995) investigating Chilean forestry workers. In their investigation, chainsaw operators and stackers expended, on average, 6–7 kcal min^{-1}, which was virtually the same as in the South African study. These findings were very different to those reported for forestry workers from developed countries, which reiterates Apud and Valdés's emphasis on the importance of conducting research on indigenous workers in their actual working environments. What was dissimilar between their findings and the findings of Christie (2006) was that Chilean workers were not undernourished. The fact that the South African forestry workers were found to be undernourished will, in all likelihood, have negative long-term consequences on work sustainability, and could possibly explain the high staff turnover. These workers are unlikely to have the required energy available to sustain this type of work effort over extended periods as the cumulative effect over many months or years will have a deleterious effect on their well being.

14.4.5.2 Energy Balance/Imbalance

Christie (2006) reported energy deficits of 8662 and 8804 kJ for chainsaw operators and stackers, respectively. These energy deficits are comparable to those of Lambert et al. (1994) who reported a deficit of 8846 kJ with sugarcane workers in South Africa. The diminished caloric intake, resulting in a substantial energy imbalance, is highly likely to negatively impact not only on the work capacity of these workers, but also on their basic health status. It was therefore deemed imperative that the most critical intervention was not so much to focus on the task, where very little could be done without major changes in the entire forestry industry, but rather to address this unacceptable energy imbalance as well as the fluid imbalance.

Following the provision of fluid and solid supplies to the workers, postintervention data revealed promising changes. Although energy expenditure was not statistically different in the postintervention stage, the relationship between the energy demands of the task and the energy intake of the workers was significantly improved (see Table 14.3). Energy

TABLE 14.3

Relationship between the Mean Energy Expenditure and Energy Intake of Chainsaw Operators and Stackers Pre- and Postintervention

	Energy Cost (kJ shift^{-1})	Energy Intake (kJ shift^{-1})	Energy Deficit (kJ shift^{-1})
Preintervention	9481.2	819.4	8661.8
	8947.2	143.0	8804.2
Postintervention	9450.4	4715.4[a]	4735.1[a]
	8892.1	4715.4[a]	4176.8[a]

Source: Taken from Christie, C.J., Physical workloads imposed on South African harvesters. Unpublished PhD thesis, Department of Human Kinetics and Ergonomics, Rhodes University, Grahamstown, South Africa, 2006.

Note: Shaded areas refer to the values obtained for the stackers.

[a] Denotes a significant difference between the pre- and postintervention stages.

intake during work increased by 3896 and 4302 kJ for the chainsaw operators and stackers, respectively, resulting in a 45% (chainsaw operators) and 53% (stackers) improvement in the energy deficit. Despite this, there was still a discrepancy of over 4000 kJ, emphasizing the high energy level required to execute these tasks, and how essential fuel supplementation is for the workers.

14.4.5.3 Fluid Balance

Christie (2006) also reported on fluid intake during work and noted that the laborers were reluctant to stop and drink or eat while they were working. It was clear that the workers were more concerned with completing their allotted tasks as fast as possible, with preference given to ingestion only on completion of their allotted work, thus enabling them to go home early. This reluctance to consume anything during work has previously been ascertained by Wigaeus Hjelm and Frisk (1985) investigating forestry workers in Vietnam. Workers consumed less than 500 mL of fluid during the work shift and lost up to 2.4 kg of body mass, which equated to 3.6%, over the course of their shift (Christie, 2006). These findings led her to propose that regular, freshwater be provided for the workers, which significantly improved their fluid status. Biggs (2006) measured urine specific gravity to determine the dehydration status of forestry workers and found that workers were starting the day in an already underhydrated state. Table 14.4 shows that only 4% of the workers started the day in a "well hydrated" state and 50% were "significantly dehydrated."

TABLE 14.4

Percent (%) Workers Falling into Each Hydration State at Various Times during the Day

	Well Hydrated (%)	Minimal Dehydration (%)	Significant Dehydration (%)	Serious Dehydration (%)
Preshift	4	41	50	5
Midmorning	3	38	57	2
Postshift	2	28	52	18

Source: Adapted from Biggs, C., Nutrition and hydration status of forsetry workers in Richmond, KwaZulu Natal, South Africa. Report for ICFR. Discipline of Dietetics and Human Nutrition, University of KwaZulu Natal, South Africa, 2006.

This is because 49% of workers drank for the first time during the midmorning break. By midmorning (prior to drinking the supplied fluid) the scenario had deteriorated and 57% of the workers were now "significantly dehydrated." By the end of the day 18% of workers were "seriously dehydrated," with some workers being unable to even supply a urine sample. These results, displayed in Table 14.1, reveal a serious need for hydration interventions to be implemented throughout the work shift.

Although the ergonomics research in Chile has resulted in many important and substantial changes with respect to energy and fluid consumption, based on the studies by Scott et al. (2004), Christie (2006), and Biggs (2006) in South Africa it would appear that food and fluid supplementation is essential. This is still an intervention which needs to be more forcibly implemented in the South African forestry industry as James (2005) found that it is not a common practice for contractors to provide food rations. Only 38% of contractors interviewed supply their workers with rations, while the remaining 62% provide "raw" wage with no rations provided.

14.4.6 Ergonomics Interventions That Work in This Industry in IDCs

To implement interventions in most developing countries a number of barriers have to be overcome. The first is tradition, which is the worst enemy of change because even if improvements are evident, not only to workers but also supervisors, they tend to reject new ways of work organization. Therefore, the idea is not to impose new modalities, but to use interactive methods and adequate training until the workers and supervisors are fully convinced that the changes are justified.

In South Africa, it was suggested by Faucett et al. (2006) that rest breaks help reduce the physical demands of the job by allowing the body time to recover and replenish energy stores. In a contractor survey carried out in South Africa by James (2005), only 28% of contractors enforce the breaks while the remaining 72% leave rest breaks up to the discretion of the workers. Even those contractors who enforce rest breaks reported that workers tend not to take breaks unless they are made to do so. A possible reason for workers not taking rest breaks of their own accord is that 66% of forestry workers work-to-task while only 33% of them work a specific number of hours (James, 2005). This results in workers performing at a sometimes exceptionally high intensity in order to complete the task as quickly as possible, generally to go home sooner, but in some cases to be able to do additional work for extra remuneration.

In Chile it has been proposed that the workers need to be involved, and understand change. A study carried out in that country to evaluate job rotation between power-saw operators was initially rejected by the workers. They said it was complicated and they were afraid that their salaries would be reduced; they also reported that the rest pauses of 10 min scheduled at midmorning and midafternoon were a waste of time. Eventually, when they experienced less strain and their earnings went up about 10%, due to the equivalent increment in output, they became very enthusiastic and all their previous apprehensions disappeared. From that point of view efforts should be made to convince workers, rather than to impose work practices, a custom which tends to be fairly prevalent in many developing countries.

It is therefore important that field workshops should be encouraged to educate workers and contractors while at the same time, encouraging input from all those involved. Emphasis should be on how to implement simple organizational measures to improve working conditions. On this basis, the number of contractors making use of ergonomics principles will be progressively increased and noticeable changes in food provision, allowances for scheduled rest pauses and job rotation, as well as the use of safety equipment and

improved work techniques could be observed in the field. However, there is still an urgent need to continue assisting the small contractors in the search of appropriate technologies. In summary, the following are considered important:

- Design and organization of forest camps and/or transport systems
- Organization of food provision
- Appropriate personal protective equipment
- Correct tools, machines and accessories, well maintained
- Training and certification of technical abilities
- Assistance in technological and organizational innovation
- Ergonomic design to optimize the use of technology
- Functional balance in the working teams
- Reduction of differences between expected output and real output
- Handling of near accidents
- Design of shifts considering output of machinery, size of the crews, job rotation, handling of rest pauses, and sequence of operations
- Follow up
- Calculation of salaries and incentives according to work demands
- Training in ergonomic aspects of work organization

14.5 Conclusion

Forestry in Chile and South Africa is still highly dependent on manual labor, and sustainable forestry is therefore dependent on sustainable human resources. The physical demands placed on these manual workers are often exceptionally high and environmental conditions generally are harsh. This, together with the escalating incidence of HIV/AIDS, particularly in South Africa, and the development of the virus into its later stages, has resulted in a decrease in worker capabilities which are also negatively impacted by high levels of dehydration and the poor nutritional status seen in many IDC workers. This has resulted in a growing incompatibility between task demands and worker capabilities, hence a decrease in worker output which in turn has a negative impact on company productivity. In order to sustain the human resources in forestry, either the tasks need to be adjusted to better suit worker capabilities or else worker well-being needs to be improved so that workers are better able to cope with the task demands. Clearly a two-pronged approach combining both would be the most beneficial for the industry.

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15

Ergonomics in the Carpet-Weaving Industry in Iran

Majid Motamedzade

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15.1 Introduction

Weaving is as old as civilization. Beside the need to design a suitable mat to sit or sleep on, primitive humans acquired more creative skills such as basket weaving using pliable grasses and barks, with the nests of birds and interwoven stems of plants being the creative patterns directing humans to weaving. Women were those who engaged themselves in this occupation, producing mats, saddles, and carriage bags.

Not much is known about the world's first knotted carpets, and what does exist was acquired by means of conjecture and assumption. In the past, European researchers believed that successive Egyptian civilizations were the pioneers of carpet weaving. Even Iranians cannot claim to have produced the first handwoven carpets, but early evidence, in the form of a carpet named "Pazirik," proves the role of Iranians in developing this valuable art. Today the Persian carpet is an essential part of Persian art and culture, and a sought-after commodity worldwide. Carpet weaving is one of the most distinguished manifestations of Persian culture and art, and dates back to ancient Persia. At present in Iran, apart from its

historical background, the carpet-weaving industry as an informal sector enterprise ranks foremost in importance and size among other Iranian handicrafts. Handwoven carpets are the most important Iranian nonoil related export products and have an outstanding place in the country's economy because of its share of 1% in gross national product (GNP) (Mahdavi, 2000). There are nearly 2.2 million full- and part-time weavers, and about 8.5 million people directly or indirectly live from the handwoven carpet industry in Iran (Sobhe, 1997). In 1999, the carpet export business comprised over 20.5% of the total nonoil export of the country (Mahdavi, 2000).

Turning to the conditions under which these carpets are woven it is generally acknowledged that in setting priorities for health services consideration must be given to (a) the size of the population at risk and the degree of morbidity, and (b) extent to which a particular program contributes to overall socioeconomic development, its effectiveness, feasibility, cost, and relative urgency (Noweir, 1986). Considering these factors and the widespread nature of the carpet industry in the country, the economic importance of the industry, the role of the industry in generating employment and the sociocultural value of the industry, it may be concluded that in Iran, as in other developing countries, attention to the handweavers' occupational health and to the improvement of their working conditions should be a major priority. The carpet industry has a considerable effect on the production, economy, quality of life, and sustainable development of the nation. This chapter outlines occupational health and work problems in our carpet-weaving industry. It proposes to review the risk factors in the industry and to present the latest adopted ergonomics solutions.

15.2 Conditions of Work in the Carpet-Weaving Industry

The author of this chapter, in his teenage years, had first-hand experience in carpet weaving as it was his father's job, and he can therefore personally attest to the suffering of carpet weavers, especially young girls and boys. The inherent beauty of handwoven Persian carpets is consequently less apparent to the author than it probably will be to the reader. Carpet weaving is a family-based job and handwoven carpets are mainly produced in home-based workshops, and in limited cases in weaving factories, where a number of weavers are gathered to produce carpets.

A carpet loom is the most important element in the weaving operation. Looms are of two types, horizontal and vertical. Horizontal looms pose a number of hazards and fortunately are less common. However, vertical looms, which are recognized as safer, create problems too. Weavers perform their job sitting on a bench or on the ground. When the ground is the seat, weaving is done in a cross-legged position. In the case of fixed vertical looms, as weaving progresses, the weaving height increases. In this situation the weaver has continually to place the seat in a higher position. The result is that when the seat is high the weaver's legs hang down unsupported. Sometimes, to prevent this, the weaver sits cross-legged on the seat. In some cases the seat is covered with soft materials, but in other cases it is not, as is evident in Figure 15.1.

While weaving a carpet, threads are held with the nondominant hand, and with the dominant hand another thread is passed between the loom threads and is then knotted. Afterwards the tip of the knot is cut with a knife, held in the dominant hand (see Figure 15.2). After two or three rows of knots have been tied the rows are compressed with an iron comb. Finally, to obtain a smooth surface, the threads are cut with scissors. The hand-tools used

FIGURE 15.1
A typical vertical carpet-weaving loom.

FIGURE 15.2
Typical hand and finger postures during carpet weaving.

FIGURE 15.3
The scares of surgical intervention for carpal tunnel syndrome (CTS) which is a common repetition strain injury among carpet weavers.

in carpet weaving are traditionally designed and no ergonomics principles were applied to their structure. Due to the poor design of weaving hand-tools and the inappropriate material used in their structures, several parts of the weavers' hands and fingers bear contact stresses which may cause soft tissue injury. As extensive use of hand-tools is a key issue in the development of upper limb musculoskeletal disorders (Figure 15.3), ergonomics improvements of these hand-tools may promote improved health and safety among carpet weavers.

Raw materials used in carpet weaving are mainly wool and threads. Sometimes these materials are of low quality or are infected with biological agents which produce health problems for the weavers. In addition the weaving workshops, which are mainly home-based, are small and cramped and generally lack adequate lighting, ventilation, cooling, and heating systems. The weavers, who are mostly women, earn low incomes and their education is mostly at a primary level. Working hours in the carpet industry are not fixed and they vary based on the situation and workload. Moreover, motivation to earn more money results in the weavers working long hours (Choobineh et al., 2003).

15.3 Work Risk Factors in Carpet-Weaving Industry

15.3.1 Awkward Postures

Due to poor design of hand-tools, weaving workstations and looms, the postures of the neck, back, shoulders, upper and lower arms, wrists, and knees deviate from the neutral position for considerable periods of time leading to a high incidence of musculoskeletal injuries. Due to there being no leg clearance when using vertical looms, the weaver is

forced to work cross-legged or in other fixed leg positions. In this situation, because there is no space for leg movements, the weaver cannot adjust her working posture in an attempt to alternate the postural stresses over different regions of the lower extremities. In a study of 1020 weavers, Choobineh et al. (2003), found the percentage of weavers who adopted suboptimal postures in the upper arm, lower arm, neck, trunk and leg to be 88.6%, 57.6%, 82.8%, 85.9% and 69.5%, respectively.

15.3.2 Repetitive Nature of Tasks

Weaving is a highly repetitive task, in which a regular weaver ties up to 30 knots per minute. During all steps of weaving, the wrist and finger flexors and extensors are used continuously, with pinching movements and forceful grasping actions. If it is assumed that the weaver works for 8 h a shift and the weaving task comprises 60% of the total working time, there will be 8640 knots tied per shift. Since these highly repetitive tasks have a cycle time of 30 s or less, weaving is categorized as a highly repetitive job (Choobineh et al., 2004).

15.3.3 Force

The weight of a weaving comb, in some cases, is more than 2 kg. As the weaver has to compress the knots by using the comb at regular intervals, its weight and repetitive application under poor postural conditions can and does result in upper limb disorders.

15.3.4 Contact Stress

Given the poor design of weaving hand-tools and the inappropriate materials used in their structure, many localized parts of weavers' hands and fingers bear contact stress, which is likely to cause injury to the soft tissues of the hands.

15.3.5 Poor Lighting

Carpet weaving is considered as precision work, for the knots are very fine and close together, and color recognition is of vital importance. Such operations require adequate lighting both qualitatively and quantitatively. In many weaving workshops, lighting is not adequate, which results in considerable eye strain, and in conjunction with this the insufficient lighting adds to the already awkward postures, as weavers are forced to incline their heads, necks, and backs to be able to look closer at their work.

15.3.6 Poor Ambient Conditions

Lack of cooling and heating systems in weaving workshops results in poor thermal conditions. This improper environment will have adverse effects on the well being of the weavers, and consequently on their performance.

15.3.7 Poor Air Quality

In the operation of wool preparation, combing knots and cleaning the workshop, wool fibers are produced and released into the atmosphere. Lack of proper ventilation in the workshop causes the weaver to be exposed to these fibers which increases the risk of respiratory diseases. Contamination of fibers with biological agents such as bacteria and fungi results in respiratory exposure to these agents and threatens the health of the weaver.

15.3.8 Chemicals

Some dyes used in wool preparation are toxic (e.g., chromate-based chemicals). Skin exposure to such toxic chemicals causes skin diseases and dermatitis (Radjabi, 1983). Biological agents such as anthrax bacillus can enter the body and produce infectious skin diseases as well.

15.3.9 Lack of Work–Rest Regime

Because there is no scheduled working time, weavers usually work continuously for long periods without rest pauses. The outcome of this prolonged exposure to the numerous occupational risk factors sited above increases the likelihood of the weavers experiencing extreme physical stress.

15.4 Ergonomics Solutions for the Carpet-Weaving Industry

15.4.1 Ergonomics Design of the Carpet-Weaving Workstation

Choobineh et al. (2007) proposed a model ergonomics carpet-weaving workstation. They conducted a comprehensive study which consisted of two phases. In the first phase, the incidents of musculoskeletal symptoms in nine Iranian provinces were surveyed by means of distributing a questionnaire to 1439 weavers, and working postures and weaving workstations were ergonomically assessed. The results of this phase revealed that problems associated with the musculoskeletal system were high. It also identified the design shortcomings of the weaving workstations. In the second phase of this study, an adjustable workstation was designed and constructed. The results of laboratory simulations showed that working postures were acceptable when the weaving height was adjusted to be 200 mm above elbow height and when a high seat with a forward slope was used. By combining the results of the two aforementioned phases, guidelines for a weaving workstation design were presented. In this ergonomically designed workstation, the loom is vertical with the seat, loom and weaving heights made adjustable, allowing enough leg room under the loom. The recommended workstation should improve the weavers' working posture, thereby reducing the postural stresses placed on the their bodies and, consequently, should reduce the prevalence of musculoskeletal problems.

15.4.2 Ergonomics Design of Carpet-Weaving Hand-Tools

Motamedzade et al. (2007), with experience in the field, proposed ergonomically redesigned hand-tools for carpet weaving. This study was conducted to investigate the design of hand-tools currently used in the carpet-weaving operation and, using sound ergonomics principles, to design or redesign the tools based on anthropometric dimensions of the workers and the tasks carried out. The study consisted of two phases, in the first of which 862 weavers from three Iranian provinces participated. A questionnaire consisting of personal details, a Nordic Questionnaire for upper limbs and a table for anthropometric dimensions of the hand were used to collect the required data. Based on the results of the first phase, prototypes of the hand-tools were made and were illustrated in Figure 15.4. As shown in Figure 15.5, a nonslip texture was used to improve the grips so increasing

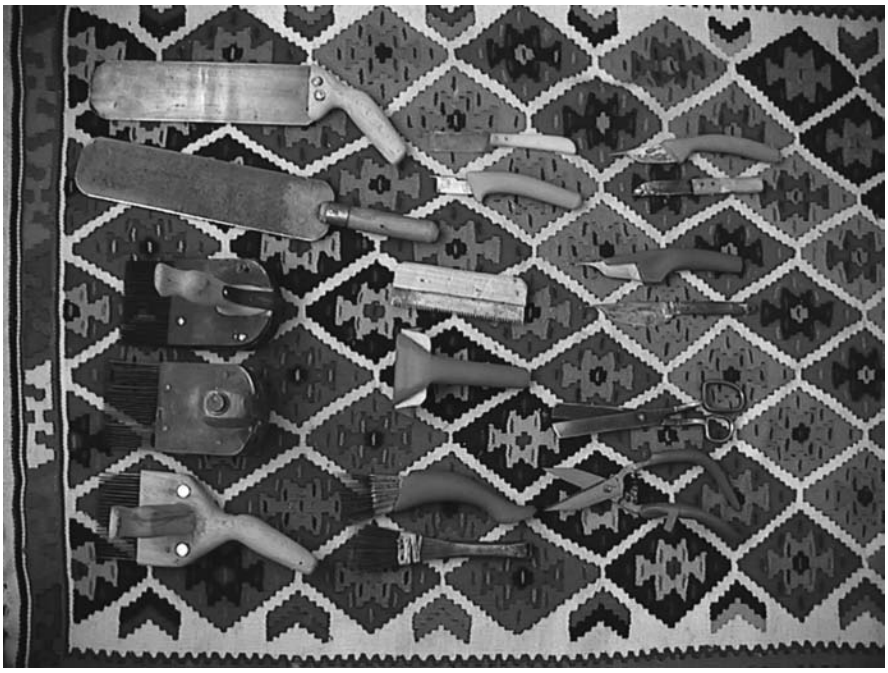

FIGURE 15.4
A collection of carpet-weaving hand-tools. For the most common tools, prototypes were designed and tested.

FIGURE 15.5
Weaving comb; left: traditional design, right: comb with redesigned handle.

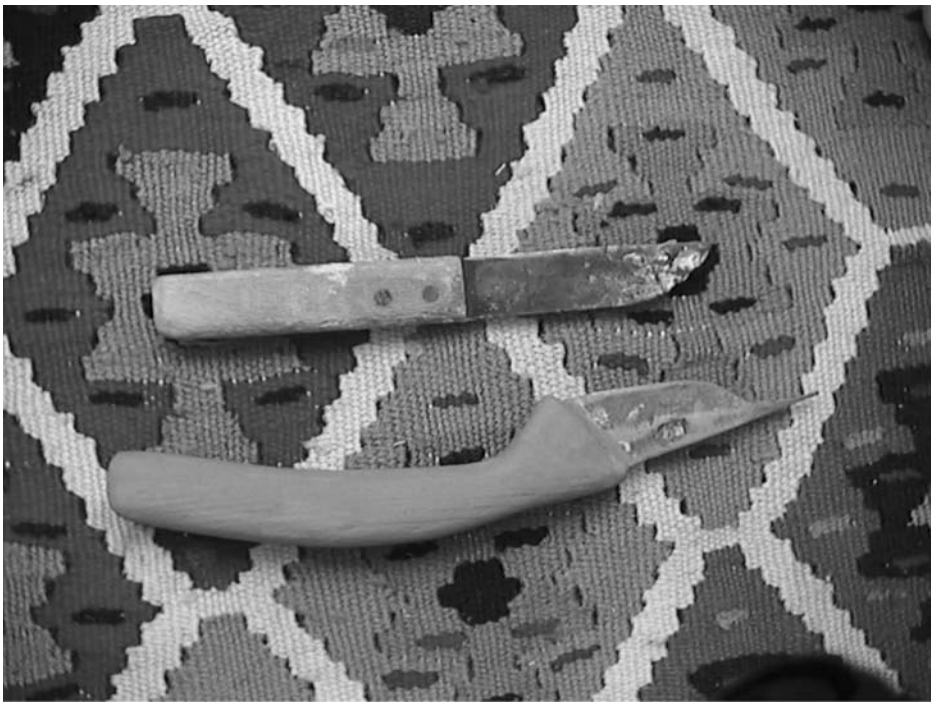

FIGURE 15.6
Weaving knife; top: traditional design; bottom: knife with new ergonomic handle.

the friction between the hand and the handle of the weaving comb. The comb handle was oriented in such a way that while working no significant deviation from neutral posture occurred. Figure 15.6 demonstrates that an appropriate nonslip texture was used to improve the grip of the weaving knife. The guard on the sharp edge prevented slippage of the hand over the blade resulting in safer use of the knife. The rounded end of the handle was extended out of the closed hand, resulting in stress reduction on the palm. In the original tool no groove was provided to accommodate wide variations in finger anthropometry of the users. An appropriate texture was used to prevent slippage and to reduce contact stress on the hand and fingers during work with weaving scissors. This can be seen in Figure 15.7. The scissors handle was oriented such that during work the wrist was held in a neutral posture and no significant deviations from this ideal position occurred. The rounded end of the handle was extended out of the closed hand, which lead to stress reduction on the palm. Figure 15.8 shows the weaver's hand posture while working with the weaving scissors.

In this study, in order to assess comfort and applicability of the designed hand-tools and the weavers' perceptions of the new design, a usability test was conducted. Ten experienced weavers participated in this test. Statistical analyses revealed significant differences between the scores of the old, and the newly designed tools (Motamedzade et al., 2007). There was a significant preference toward the comfort and applicability of the prototypes. The new ergonomically designed weaving hand-tools were found to be applicable and acceptable by the carpet weavers.

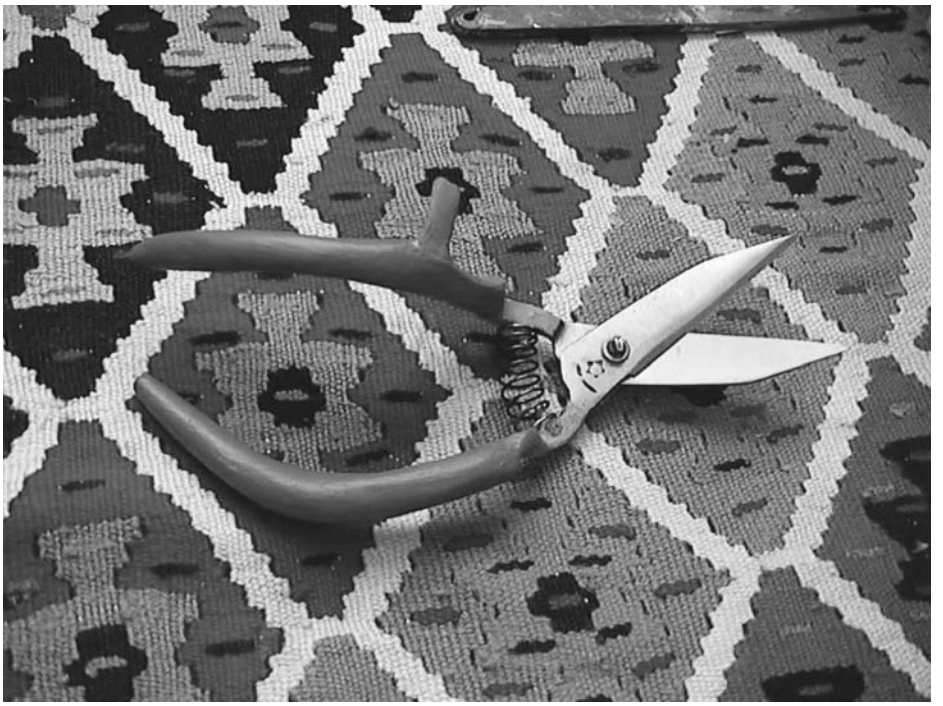

FIGURE 15.7
Ergonomically designed weaving scissors.

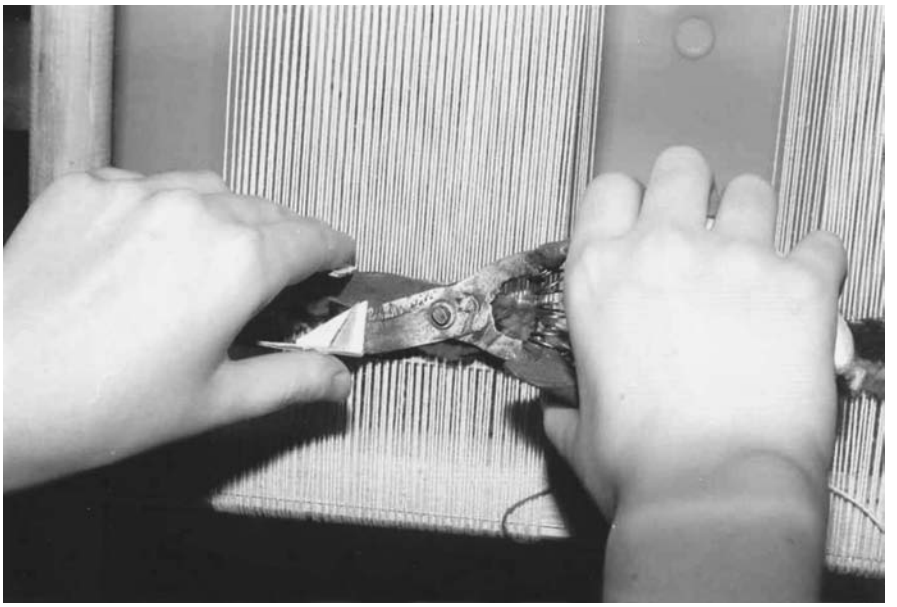

FIGURE 15.8
Weaver's hand posture during work with the weaving scissors prototype.

15.5 Conclusions

Personal experiences of the author and others cited show that musculoskeletal problems in the hand-weaving carpet industry occur at a high incidence rate. Thus, improvement of working conditions and control of musculoskeletal risk factors is essential. Since the majority of factors for developing musculoskeletal problems among weavers are attributable to poorly designed weaving workstations and tools, any ergonomics interventional program should be directed toward their design.

Finally, in industrially developing countries, great efforts are directed toward encouraging the development of small-scale industries as an engine for growth in their economies. If the carpet industry is supposed to work as a powerful engine to bring positive economic outcomes for countries where it is a key industry, it should receive appropriate attention from different viewpoints, above all ergonomics. Given this, as the carpet industry, like other informal small-scale industries around the world, faces serious problems such as lack of registration and monitoring, lack of legislative support, exclusion from health and safety acts and regulations, low capital resources and income, and finally low priority of health service planning, it seems that intervention programs for improving working conditions in the carpet-weaving industry in developing countries, need local government involvement, and should be planned, sponsored, and implemented by the governmental organizations responsible for occupational health and safety affairs, in cooperation with national/regional ergonomics societies.

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16

Nonfatal Accident Analyses in the Textile Industry in India

Pranab K. Nag, Anjali Nag, and Heer Vyas

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16.1 Introduction

Workplace accidents are the leading cause of injury, morbidity, and mortality among industrial workers, resulting in lost working hours, medical treatment, restriction of work or incapacitation, and in the worst case, death. The focus of this chapter is on nonfatal accidents. The overall human, social, and financial toll of traumatic occupational injuries is enormous, rivaling the social burden imposed by such health threats as cancer, HIV, and CHD. The direct costs (lost wages, medical, rehabilitation and insurance costs, production loss) of occupational injuries in the industrially developing countries remain elusive. Leigh et al. (1999) estimated around 16 million injuries every year, with 2 million moderate to serious injuries on the Indian subcontinent. Indirect costs, such as pain and suffering by workers and family members, are very evident, but a major limitation in dealing with this negative scenario is the inappropriate accounting of the accident events and the potential risks for work-related injuries.

This chapter presents an analysis of occupational accidents and traumatic injuries in the textile industrial process. Of the world's total textile production, the industrial enterprises of the Asia-Pacific region contribute two-thirds, to the tune of about 50 million tons of fabric annually. Accident data from the textile industries in this region are sporadic. The prevalence of work hazards, and the quantitative relationships between the nature of work and workplace accident causation are conspicuously lacking. In India alone, nearly 13,500 enterprises employ about 2 million workers in the textile sector. The work processes in these industries require intense human involvement under suboptimal working conditions which culminate in a high incidence of accidents of varied severity, some of them fatal. An ILO (1997–1998) study in Vietnam indicated that textile workers were exposed

to hot and noisy environments, and these workplace exposures led to many accidents at work. The study of Lithuanian textile workers by Ustinaviciene and Piesine (2007) reported 9.3% injuries, with an increase in morbidity with age, and women having 1.5 times higher morbidity than men. Fritschi et al. (2004) reported data from Australian textile units which show that workers, particularly men, are at high injury risk. The shift schedules in work of this nature also have a significant influence on the health, sleep length, social activity, and problem intensity of textile workers (Pajunen et al., 2007). The present chapter constitutes a descriptive analysis of accident patterns and injuries among the workers in selected Indian textile units, and a record of those injuries, such as cuts, fractures, sprains, amputations, which result from a work-related event or from a single instantaneous exposure in the work environment.

16.2 Methods

Accident data were collated from 11 selected textile units in the city of Ahmedabad, which is often called the "Manchester of India," since an ever-increasing number of textile firms have dotted the city skyline over the century. Epidemiological analyses, risk analyses, safety attitudes and behavior, case studies, and near-accident studies have all provided information on work accident. There are different criteria for reportable accidents in different countries. As stipulated under the Indian Factories Act of 1948, only those accidents in which the injury occurred while working on the industrial premises, and in which the severity of the injury medically forced the person to be away from work for at least two days, were included in the analysis. The injuries were recorded by the safety department and medical staff of the industry, and reported to the factory inspectorate.

The present analysis included 10,540 nonfatal accidents from three year retrospective data and a one year prospective study in the selected textile units, excluding fatal accidents. A month-to-month count of over 214 months revealed approximately 50 accidents per month. The checkpoints for accident records included information about the organization, textile subunits, details of the injured person (e.g., sex, age, education, job title), characteristics of the workplace and the description of the event, the date and time of accident, the body part(s) injured, duration of absence from work, and general health complaints. The circumstances of each accident were reviewed, including the narrative description of "how the injury occurred."

16.2.1 Textile Operations

Textile workers produce fibers, cloth, and upholstery, and fashion them into the finished products used in our daily lives. Woven fabrics are used to make apparel and other goods, whereas some knitted products (hosiery) and tufted products (carpets) emerge in the near-finished form. The first step in textile production is preparing the natural or synthetic fibers. Extruding and forming machines extrude or force liquid synthetic material (such as rayon and liquid polymers) through small holes and draw out filaments. The natural fibers (such as cotton and wool) are processed through carding and combing machines that clean and align them into short lengths called "sliver." In making sliver, the operators combine the natural fibers and synthetics filaments to give the product the desired texture and other characteristics. Yarn quality control is critical in the production line. The warp and

sizing operations are the next processes. In winding, twisting, and drawing-out machines, the operators take the sliver and draw out, twist, and wind it to produce yarn. After the preprocessing of weaving is complete, the weaving process starts, followed by inspection. The knitting and weaving machines weave, knit, loop, or tuft the yarn into a product. The bleaching and dyeing machines wash, bleach, or dye both yarn and finished fabrics.

16.3 Results

The study showed that the work patterns in 11 textile industries have a definite influence on accident causation. The textile industries included in the study are semimechanized. The local practices, power staggering, endemic human–machine relationships, environmental factors, temporal events, work conditions, and particular pressures on "Badli" (substitute) workers were noted. We analyzed the variation in injury patterns with age, department, and shift patterns. Age-wise distribution of data indicated that about half of the accidents took place among workers in the age group of 21–35 years, and almost 40% took place among the workers in the age group of 36–50 years.

For the total number of individuals affected by accidents, and for the relative distribution of injuries (see Figure 16.1), which illustrates that fingers and legs accounted for the highest number. The index fingers were maximally affected in accidents, as shown

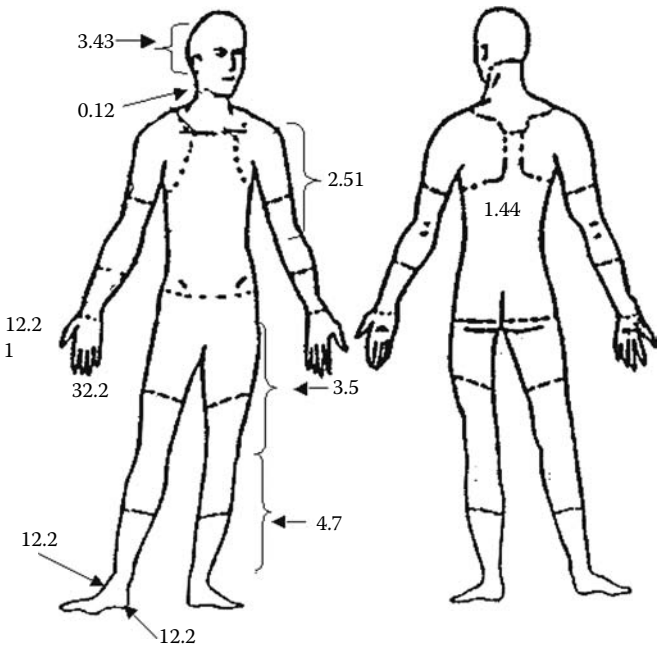

FIGURE 16.1
Percentage distributions of accidents in body segments.

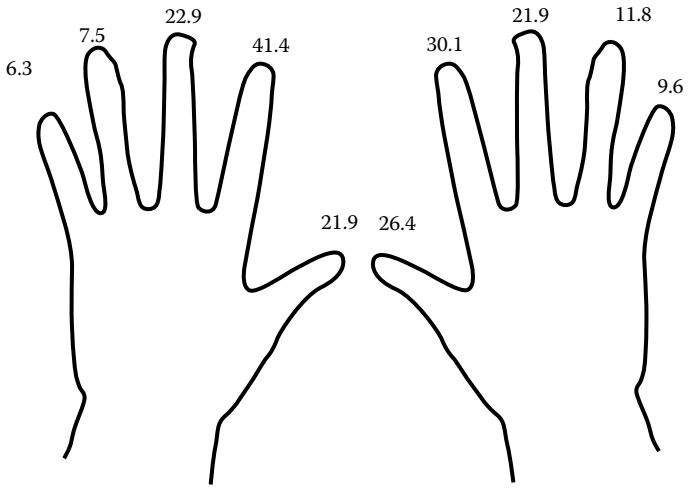

FIGURE 16.2
Percentage distributions of accidents in right and left hand.

in Figure 16.2. However, the injury frequency of the right index finger was distinctively more than for the left hand. The majority of accidents, in respect of the lower extremity, were on the feet and legs.

The city of Ahmedabad is extremely hot throughout the summer season. The tropical heat, combined with humid conditions maintained due to the demand of work processes in textile workers, as well as high physical intensity of work patterns all contribute to casualties at the workplace (Nag et al., 2007). The months of May and June recorded highest number of accidents (see Figure 16.3), while the cooler month of November had a lower rate of accidents. Other temporal factors such as date and shift-wise variations had more complex patterns. The date-related distribution of accidents (Figure 16.4) shows that relatively more accidents occurred during the first and third week of every month. Incidentally, payday was in the second week of every month. In the earlier study of accidents, on a relatively smaller sample size, the investigators recorded the highest number of accidents on the tenth day of every month. In the present study, the highest recorded injury remained in the

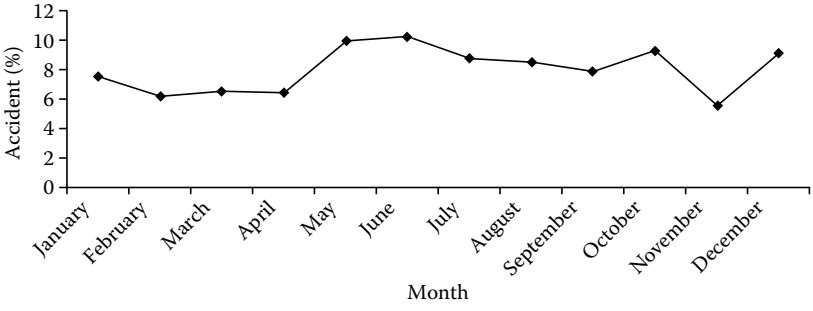

FIGURE 16.3
Month-wise distribution of injury.

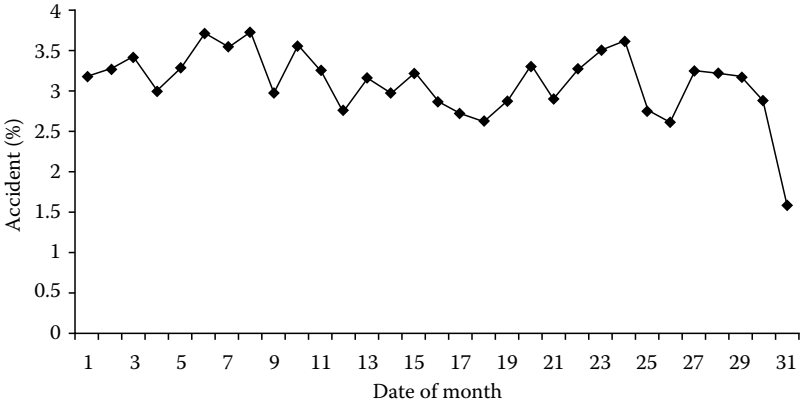

FIGURE 16.4
Date-wise distribution of injury.

second week of the month, particularly on the eight day each month. The trend appeared to be similar in a larger sample size. Inattentiveness to work was the assumed cause of these higher accident rates. Most textile workers live under personal financial constraints and often need to borrow against their monthly incomes. On the subsequent couple of days after payday, workers probably have a sense of relief of burden and are therefore able to be more attentive at work. The third week of the month showed an increased number of accidents, followed by decline in last week of month. Generally, the number of accidents was marginally less in the second half of the month.

The shift-related variations in the accident pattern are shown for each month shift-wise (Figure 16.5), and on each date shift-wise (Figure 16.6). Of 10,540 accidents studied, 5,057 accidents occurred in the morning, 3,746 in the afternoon, and 1,737 in the night shift. The trend of the present data indicates an initial increase in the rate of accidents in the morning shift. The hourly distribution (Figure 16.7) shows that the last hour of the first and second shift recorded the highest number of accidents. In the night shift, the first hour recorded the highest number of accidents, and then showed an upward trend in accident rate in the fourth and fifth hour. With the data grouped in first and second half of each shift, it was

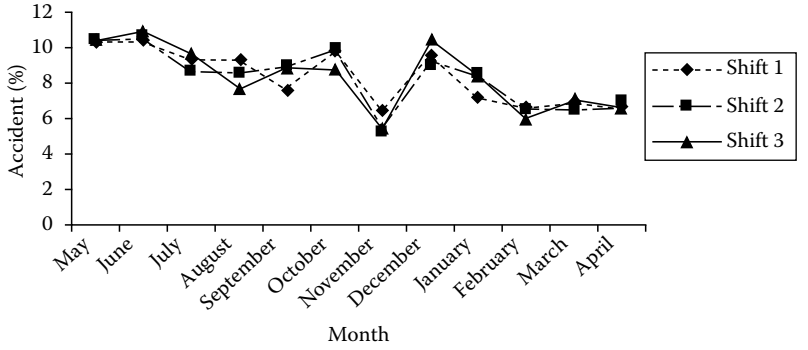

FIGURE 16.5
Shift-wise distribution of injuries (monthly variation).

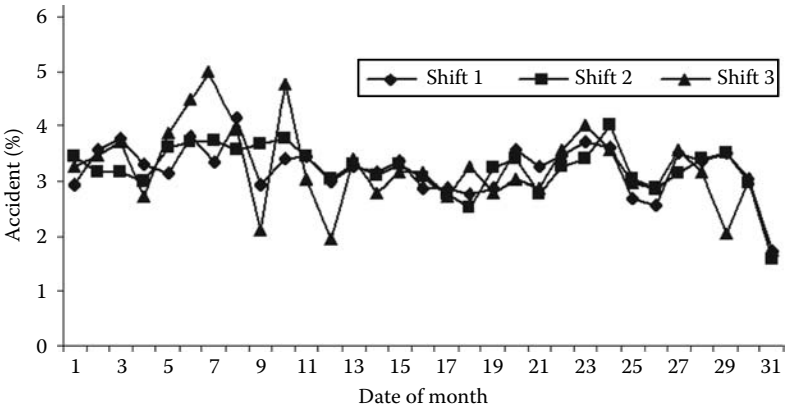

FIGURE 16.6
Shift-wise distribution of injuries (daily variation).

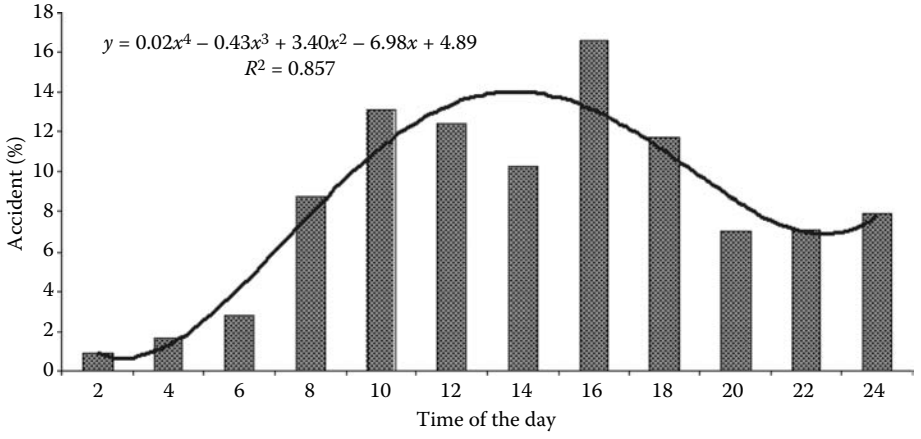

FIGURE 16.7
Hour-wise distribution of injuries.

evident that 60% of accidents in the morning shift occurred in the first half of the shift. In the afternoon shift, accidents were uniformly distributed, with 52% accidents in the first half. On the other hand, in night work 57% of the accidents took place in the second half of the shift.

Most textile industries included in the study are only semimechanized. The causative accident factors listed are human body struck by spinning/rotating/falling objects and/or caught in moving parts of machinery; work overexertion (e.g., materials handling); environmental stresses, including noise and heat, falls at different levels; missing hand holds; change of behavior by sleep disturbances and time pressure. As a general practice in industry, injuries are immediately attended to at the on-site clinic or nearby employee state insurance medical center.

The number of workers employed in the different processes of the textile works varies with each industry, depending on their fabric manufacturing priority. Data analysis

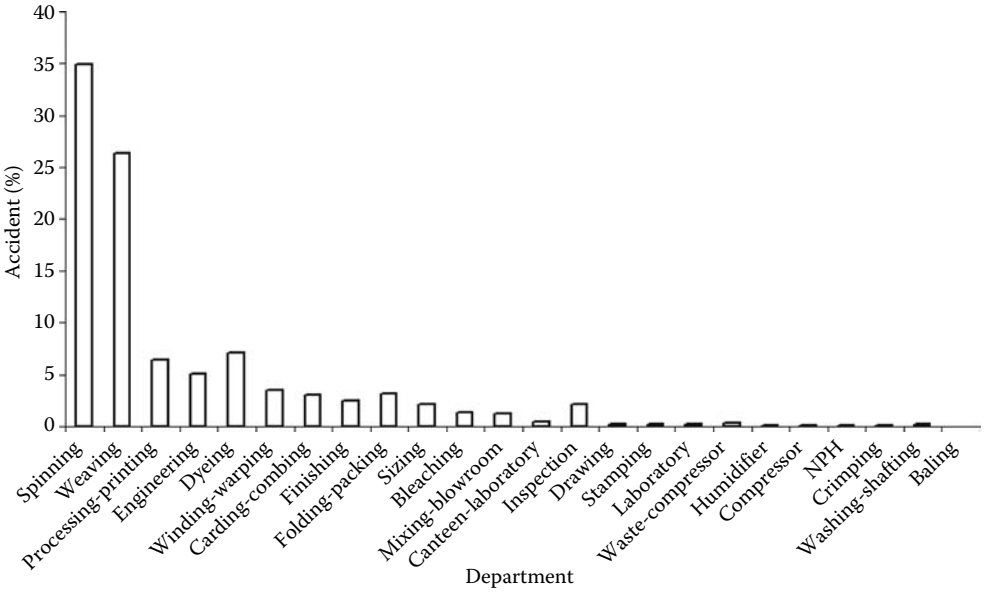

FIGURE 16.8
Department-wise breakup of accidents.

primarily indicated that nearly one-third of incidents were reported by workers involved in the spinning processes. The ring frame section in spinning continues to be the major risk area. The department-wise breakdown of accidents is given in Figure 16.8. Spinning (34.9%) and weaving (26.4%) cumulatively reported over 60% injuries. Spinning recorded the highest number of accidents, of which the ring frame accidents (20.7%) were the most frequent. Material and structural parts of machinery and tools were the most common external agencies involved in accidents.

16.4 Discussion

Nonfatal accidents in the textile industry in India are the culmination of several factors, such as human–machine incompatibility, poor methods of work, suboptimal working conditions, temporal factors, and environmental stresses. Employment structure, regulations, and the overall work scenario are peculiar, influencing the occupational health of the workers. Occupational injuries are responsible for high morbidity and mortality in India (David and Goel, 2001). Work-groups such as laborers, farmers, tradesmen, and craftsmen are at higher risk, and personal attributes of being young, males, having psychometric disorders and smoking increase the risk of injuries (Bhattacherjee et al., 2003). Work-related exposures to longer working hours and less job involvement, unsafe work conditions, and unsafe acts all contribute to the likelihood of injuries (Ma et al., 1991; Tiwari et al., 2004). The premise is that preventing and interpreting injury requires analysis of frequency, severity, causes and near-miss incidents (Jensen et al., 2004). The analysis of the present injury frequency patterns yielded the view that primary prevention could avoid many of these injuries. The consequences of the injuries are painful and disabling because of inadequate injury management. The association of temporal factors (e.g., monthly, date,

time, and shift-wise variations) with the occurrence of accidents in textile industry substantiated the observation of Hallsten (1990), whose study of 31,580 work accidents in four different industries over a period of two years, showed that accident peaks occur in morning hours across different occupational groups. The causative factors herein identified for injuries in the textile industry (factors such as those listed above) have been corroborated in other studies (Goldenhar et al., 2003; Sorock et al., 2004; Cordeiro, 2002).

The suboptimal working conditions are the potential risks which are more likely to cause accidents (Fischer et al., 1998). Shift work influences biological variables which follow a circadian rhythm (Knutsson, 2003). Workers with sleep disturbances, insufficient sleep and insomnia experience higher injury rates (Nakata et al., 2005). A similar study found that workers with better sleep quality have lower injury rates (Edmonds and Vinson, 2007). Shift-related heath disturbances such as sleepiness, sleep disturbances, chronic fatigue, and oscillatory fluctuations of alertness and vigilance are known contributors to human error and thereby to work accidents and injuries (Costa, 2003). The present study reiterates two main risk factors, i.e., the start-up of the working period and the phase of accumulated fatigue. From the beginning of the work-shift, the cumulative effect of working tempo steadily raises the possibilities for risks of accidents. This is evident in the case of the morning shift, i.e., after 3 h of work there is a transition in the situation in which human acts and movements are controlled by the demand of speedy work. A similar trend was observed for all the shifts, where workers reported highest injuries in the fifth or sixth hour of each shift. Mental and physical fatigue steadily builds in the workers in the later hours of their shift (Goldenhar et al., 2003; Simpson et al., 2005). Compared to the morning shift, the rate of accidents is relatively less in the afternoon, with no major difference between the first and second half of the shift. Despite the fact that accidents during the night shift are fewer than in other shifts, there is a consistent rise in the percentage of accidents, reaching a peak in the fifth or sixth hour. This is considered a dangerous period and the accident rate peaks before lunch break. It is evident from the statistical analysis that more accidents occur during the first half of the morning shift, compared to the second half. Activities in weaving and engineering departments appear to have higher risks of accidents in the first half of the morning shift.

Research has been conducted in certain parts of the world where the injured body segments have been identified together with the characteristics of the injury. Canadian occupational injury data over a 10 year period found that fingers, back, head, and eyes are the body segments most injured by objects, overexertion, low work standards, and inadequate job/task/tool design. The nature of injuries was sprains, bruises, and cuts (Amell et al., 2001). American day laborers suffer from injuries such as falls, burns, lacerations, and crush (Walters et al., 2002). The identification of body segment and the nature of risk factors helps to prioritize intervention strategies. In our study, workers reported more injuries to the hands, which corroborates the findings of Jones and Kumar (2004) and Aggazzoti et al. (2006). Thus the upper extremities require special personal protective equipment, and industrial management should ensure the use of such protective devises in order to reduce hand injuries. Age-related differences have been found in the distribution of nonfatal injuries. Li et al. (2002) and Wadsworth et al. (2003) reported that older workers are at higher risk of injuries because of the physical decline in visual activity, hearing and mental alertness with aging. But in the present study it was the younger workers who reported more injuries. This concurs with the findings of Nakata et al. (2005) and Aggazoti et al. (2006), and the reasons could be that the younger workers tend to be more careless, less attentive, and have less experience. Safety training might decrease number of workers getting injured.

As observed, "ring frame" accidents appear to be more than expected in the first and second half of the afternoon and night shifts, particularly in the tasks of carding and combing. This suggests that there are relatively more risks when using the ring frame. In general, the higher percentage of accidents in the later part of the night shift may be attributed to performance decrement, fatigue, and lack of arousal, associated with disturbed circadian rhythms. The available data suggest that there is a slow down in production rate in the night shift. The study observed that the performance of the night workers is unlikely to match that of morning-shift workers. There is also the opinion that people on permanent night shift might have a better work performance than those on other rotating systems.

According to the textile workers, there may be nondangerous work disturbances, without resulting in recognizable accidents. Often the workers, even in a seemingly familiar task, do not recognize potential danger or hazards. Besides the recording and analysis of near-accidents, Carter and Menckel (1985) have added the importance of proactive risk analysis in textile industries. Information mediation and the development of workers' understanding to identify a potentially dangerous situation and to deal with it adds to strategic accident prevention and safety program. The current industrial sites have no comprehensive safety programs (i.e., systematic accident investigation, job safety analysis, prevention awareness, injury database, safety rules, and manuals) to ascertain and confront risks associated with accidents. At present, the work schedule in the textile industry has been executed through negotiated agreements between employer–employee unions. Decisions have rarely been taken on any ergonomics considerations to effectively improve workers' safety, comfort, health, and productivity (Leamon, 1994). Based on health and safety considerations, it is suggested that options may be examined for change in work patterns during night shifts, and in monthly rotating shifts. Night work, particularly in the second half of the shift, results in a considerable number of accidents in the ring frame and processing departments. The afternoon workers seem to perform better, and the morning shift needs special attention for safety promotion.

The view prevails that accident prevention in the textile industry needs situation-specific planning involving human, technical, and organizational aspects. Technical measures involve the redesign of the human–machine interface, methods of work, installation of safety guards on machinery, and the like. Technical considerations in accidents are not major factors, for as noted, the main problems encountered in accidents are concerned with the lack of organizational commitment and decision making on issues related to occupational health and safety. In view of the significant temporal influence on injury occurrence, safety promotion and joint optimization of work scheduling are obviously important.

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17

Below the Surface of Practical Application of Ergonomics in Mining

Petrus C. Schutte and Jonathan P. James

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17.1 Introduction

Mining operations in industrially developing countries (IDCs) are frequently associated with difficult working conditions, and mining is considered to be one of the most physically

demanding occupations. In addition, mining equipment used in both industrially advanced countries (IACs) and IDCs is frequently designed only for functionality without considering basic ergonomics principles such as the anthropometry and functional capabilities and strength of the users.

In South Africa, the mining industry covers a large variety of mining operations, ranging from a highly sophisticated formal sector involved in ultra-deep-level mining (mining at depths of greater than 3500 m) to an informal or subsistence mining sector, both of which present unique challenges in terms of the application of ergonomics. For the major part of the previous century, ergonomics research in the South African mining industry primarily focused on the capabilities and limitations of individuals to perform physical work in conditions typical of mining, and the design of selection criteria to assess "fitness for work" on the basis of an individual's physical attributes. With the more recent emphasis on worker productivity and occupational health and safety, the implementation of ergonomics programs and a focus on the design of mining equipment has been identified as a major prerequisite in assisting the sector to reach the goal of providing the safest working environment possible for miners.

This chapter covers selected examples of practical works which have significantly improved the understanding, approach to, and efficacy of ergonomics interventions in the South African mining sector. While the overall benefits of the respective programs presented in four separate case studies have been difficult to quantify, a simple "cost-benefit" analysis will be provided for each of the case studies, thereby highlighting the impact made in enhancing the workplace for the miner.

17.2 Four Case Studies—"Mining Ergonomics Programs"

17.2.1 Implementing Ergonomics Programs in the Mining Industry

17.2.1.1 Problem Addressed

The lack of application of basic ergonomics principles, poor design of mining workplaces, and the lack of a strategy for introducing ergonomics into the South African mining industry have been identified as major contributing factors to the increase in work-related injury and occupational disease in South African mines. A lack of ergonomics research pertaining to the local mining industry has also been identified as a major shortcoming and significant contributing factor (Harper, 1997). Basic ergonomics is currently only applied to a very limited extent in the South African mining industry, this despite substantial research being carried out in the area of mining ergonomics. One of the major stumbling blocks has been the lack of structure or coordination in the efforts to apply ergonomics and, as a result, no strategy for the implementation of programs has been incorporated across the sector. Previous research has stressed the need for a comprehensive ergonomics strategy for the South African mining industry. In order to address this need, a focused study was conducted to develop a plan of action to facilitate the coordinated and integrated introduction and implementation of ergonomics in the South African mining industry (De Koker and Schutte, 1999). This case study examines the challenges, changes, and examples of successful execution of ergonomics programs in selected South African mines.

17.2.1.2 Proposed Solution

The solution development process required detailed and ongoing consultation. A formal development process was followed for producing a draft ergonomics strategy for the South African mining industry. A representative sample of role players in the local mining industry was then consulted to determine the feasibility of the proposed implementation strategy. Feedback from these role players was used to refine the proposed guidelines, after which proposals were formulated for the practical realization of the strategy. Role players were again consulted to assess the feasibility of the application of the proposals. The proposed strategy involved four groups of role players, namely government, employers, employees, and manufacturers/suppliers of mining equipment, and was run on the basis of participatory ergonomics. The specific involvement proposed for the role players entailed the reviewing of existing legislation which addresses ergonomics, the drafting of an ergonomics implementation plan by government, the establishment of formal ergonomics programs on the mines by employers, the active participation and involvement in the ergonomics programs by employees, and the use of ergonomics design guidelines and specifications suitable for the local user population and mining conditions by manufacturers/suppliers of mining equipment.

17.2.1.3 Programme/Work Approach

The plan to implement the ergonomics strategy in the South African mining industry involves all four major role players in the industry by means of specific activities, and also the integration of these activities through the process of participatory ergonomics. The activities or steps required to facilitate the implementation of the strategy are the following:

- Macroplan for the implementation of the ergonomics strategy (state)
- Legislation-generation program (state)
- Formal ergonomics program for the workplace (employers)
- Participation program in the ergonomics initiatives (employees)
- Ergonomics design criteria program (manufacturers/suppliers)
- Ergonomics information flow program (manufacturers/suppliers)

Although these programs are assigned to specific role players, the active participation of all role players to ensure a coordinated and integrated implementation of ergonomics is required; i.e., the process of participatory ergonomics should be followed. In order to inform and sensitize all role players and also to increase the general level of awareness with respect to ergonomics in the mining industry, ergonomics introductory programs, and ergonomics promotional programs are required. Basic introductory training in ergonomics is a prerequisite for the successful implementation of ergonomics programs on mines. Ergonomics education and training programs, the contents of which are determined by the level of knowledge required by respective role players, are also necessary to foster constructive and active participation in the program. The final proposed ergonomics strategy for the South African mining industry, with implementation proposals, is graphically illustrated in Figure 17.1. The basic principles of ergonomics (human–machine interface) are evident, depicting a human making use of technology to perform a task in a workspace within the physical and psychological work environment. The four main role players

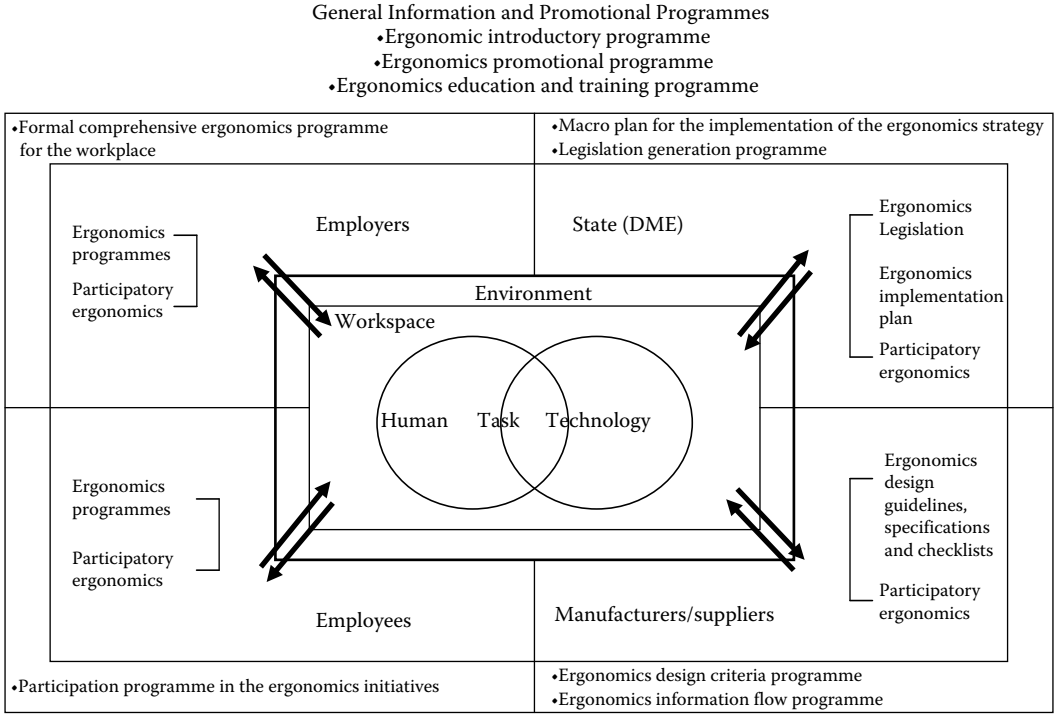

FIGURE 17.1
Graphical illustration of the ergonomics strategy and implementation proposals.

and their specific involvement methods are also illustrated, together with implementation proposals in the form of specific programs for each role player. Since the strategy is based on participatory principles, participatory ergonomics appears in each of the four role player blocks. General information and promotional programs to inform role players about, and sensitize them to the ergonomics strategy, and to increase the general level of awareness with respect to ergonomics, are listed in the outside frame of the graphical illustration.

In developing the materials required to implement the ergonomics strategy in South African mines, an enhanced model was developed (Schutte et al., 2007). Figure 17.2 demonstrates the key components of the proposed model for the South African mining industry. Essentially the model requires the development of a broad base of awareness of ergonomics principles in Step 1 and is concluded by Step 9 when the mines are encouraged to seek assistance with complex problems which are not directly resolved at a mine level. The model has been used on numerous mines in South Africa with a focus on differing areas of operation. The intention of the basic model is firstly to increase the ergonomics awareness at the operation under consideration, while also obtaining management commitment. The basic setup of the program is then established along with a specific workgroup who are responsible for attending training sessions and for assisting with the baseline hazard identification risk assessments (HIRAs) for the mine. Steps 6 and 7 include the identification of high-risk areas and the implementation of the action plan, respectively. The final two steps are to evaluate the program and to obtain assistance for complex problems.

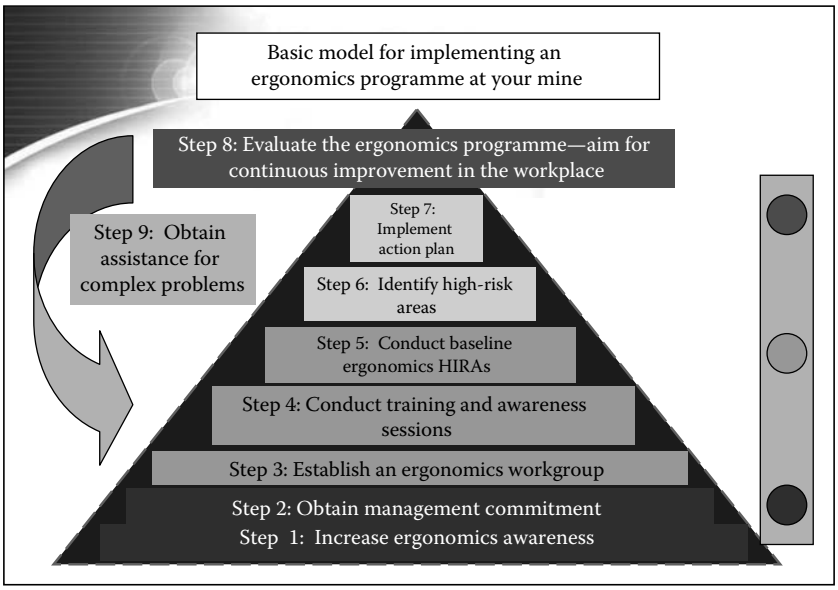

FIGURE 17.2
Ergonomics implementation model for South African mines.

17.2.1.4 Measures of Success

The above model, based on the comprehensive mining strategy covered in this case study, has contributed significantly to the implementation of ergonomics in the South African mining industry. The approach of involving all major role players (the state, employers, employees, and manufacturers/suppliers) has been effective and could be used as a blueprint by all IDCs. Ergonomics programs, which form part of the strategy, have facilitated participatory ergonomics by involving the employees in planning and controlling a significant proportion of their own work activities. The pilot program has resulted in substantial interaction between workers and managers. The participatory approach has been shown to be most successful in ensuring a change in workplace behavior (Wilson, 1994; Scott, 1997; Kogi et al., 1998). In the South African mining industry, there appears to be a specific need to ensure that the participatory approach is more widely adopted, so that employees understand the reasons for workplace changes before the implementation process commences.

17.2.2 Managing Worker Fatigue in South African Mines

17.2.2.1 Problem Addressed

There have been several high-profile accidents in the South African mining industry where fatigue was identified as either causal or contributory. Operator fatigue is a critical safety issue that affects all modes of mining, especially where shift work takes place (Schutte and Maldonado, 2003). Fatigue is a general term used to describe a wide variety of conditions. In a mining context, fatigue could be defined as a state of impaired mental and/or physical ability and lowered alertness arising as a result or combination of hard physical and mental work, health and psychosocial factors, or inadequate restorative

(a) (b)

FIGURE 17.3
Examples of two of the physically demanding tasks executed in the mining industry: (a) digging and (b) drilling.

sleep. Figure 17.3 illustrates just two of the many physically demanding tasks, which are required of the underground operators on a daily basis.

The risk of fatigue is inherent in any work setting involving shift work, long hours of work, irregular hours, extended work hours, and work which is physically or mentally demanding, repetitive, or requiring high vigilance (Hanowski et al., 2003; Mabbott and Lloyd, 2003). Fatigue can lead to accidents because it affects a number of key mental and physical abilities and can result, for example, in impaired concentration, poor judgment, reduced hand-eye coordination, and slower reaction times. Industrial workers under thermal stress for extended periods become fatigued. Physical fatigue has been identified as a causal factor in heat exhaustion and attributed to several physiological disturbances such as excessive cardiovascular strain and hyperthermia (Brake and Bates, 2002).

17.2.2.2 Proposed Solution

Management of fatigue is not simply a matter of correct shift scheduling; a more comprehensive approach is needed. In order to be successful, a fatigue management program should address the unique needs of the operation in which it is to be implemented. It should be integrated into the normal operations, and it should encourage active participation. A fatigue management program should address task- as well as worker-related factors associated with worker fatigue. In order to make the fatigue management program as practical and comprehensive as possible, BHP Billiton (2005) emphasis needs to be placed on:

- Structure and design of work-time arrangements
- Ergonomics design of workplaces and mining tasks
- Employee fitness for work
- Management processes for monitoring and controlling a worker's potential for fatigue
- Fatigue-related education and information
- Employee assistance programs

17.2.2.3 Program Approach

The management of fatigue is a shared responsibility between the organization and its employees. Fatigue management programs should be based on participatory principles to ensure successful implementation and participation of all stakeholders. The first step in the development and implementation of a fatigue management program is to secure and maintain senior management commitment. A fatigue management programme needs visibility and support at the highest management levels in the organization in order to be successful. Ideally, the chief executive and board of the organization concerned should define and document their fatigue alertness management policy to provide the foundation for the organization to tackle fatigue and manage alertness (Gertler et al., 2002).

The next step is to develop a culture in the organization in which everyone accepts that fatigue is a barrier to excellence in safe production and to worker wellness, and everybody needs to work together to overcome this barrier. On the basis of the experience gained during the implementation of fatigue management at mines, it seems that the management/employee approach (where both management and employees actively participate in the development process) will render the desired results when a fatigue management program is put into effect. Once commitment is obtained from all stakeholders fatigue within the workplace is managed by using a risk management approach.

There are five basic steps in the risk management process:

- Identifying hazards
- Assessing risks that may result because of these hazards
- Deciding on control measures to prevent or minimize the level of risks
- Implementing control measures
- Monitoring and reviewing the effectiveness of control measures

There are two methods for identifying fatigue-related hazards in the workplace:

- Risk assessment
- Incident (or accident) investigation

In the present context, risk assessment is about recognizing workplace hazards, which could potentially contribute to fatigue. Both of these methods are used in a safety management system for reducing risks, the one proactive, and the other reactive (Energy Institute 2006b).

It is advisable to consult with the workforce and talk to supervisors to identify if any of the following factors exist:

- Roster design factors (night shifts, including the number of consecutive night shifts; shift length; breaks during shift; shift start/finish times; rest periods between shifts)
- Task-related factors (repetitive or monotonous work; sustained physical or mental effort, and complex physical or mental tasks)
- Work environment factors (noise; air pollutants; vibration; temperature extremes)
- Nonwork related factors (travel time before and after shifts; sleeping disorders; substances likely to cause drowsiness or prevent sleep)

Once hazardous workplace factors have been identified, it is necessary to assess the risks associated with these factors. Risk assessment is the process of estimating the likelihood of occurrence of specific undesirable events (the realization of identified hazards), and the severity of the harm or damage caused, together with a value judgement concerning the significance of the results. It therefore has two distinct elements: risk estimation and risk evaluation. These value judgements are then used to prioritize further action and interventions. Interventions to manage fatigue due to work-time arrangements (shift work), or the potential consequence include, but are not limited to, the following (Health and Safety Executive, 2006; Energy Institute 2006b):

- Use forward rotation (morning/afternoon/night), i.e., rotate forward to a later shift rather than backwards to an earlier shift.
- Allow seven to eight consecutive hours of sleep in every 24 h.
- Reduce night work as much as possible: restrict number of consecutive night shifts to four maximum, if possible.
- Allow at least two days off following night shift.
- Avoid keeping workers on permanent night shifts.
- Early or first shift starts should be no earlier than 0600 h and no later than 0700 h.
- Provide at least two breaks of sufficient length to have a meal (20 to 30 min) in a 12 h shift and at least one long meal break in an 8 h shift.
- Plan some weekends off, advisably at least every three weeks.

Employee fitness for work is an important component of fatigue management and preplacement assessments and regular health surveillance involves a medical and/or physical assessment that determines an individual's capabilities and limitations with respect to the physical demands or requirements of a specific job. Preplacement assessments also focus on the identification of sleep disorders and other health, and medical conditions, which might impact on an individual's ability to cope with fatigue.

Management processes for monitoring and controlling a worker's potential for fatigue are essential in fatigue management. The work environment should be such that an employee will make a decision to stop work and report to management when fatigued (without loss of earnings), rather than continue working and risk a fatigue-related incident. A novel idea in this regard is the so-called "sleep contract" (Energy Institute, 2006a). A sleep contract is a negotiated and agreed framework for managing fatigue on a day-to-day basis that is integrated into an organization's existing safety management system. A sleep contract provides a formal documented structure for identifying and reporting fatigue risk, the immediate response to fatigue reports and how reports of fatigue risk will be recorded, reviewed, and addressed on an ongoing and long-term basis. The document makes it clear that employees and management are jointly responsible for fatigue risk management and states the responsibilities and accountabilities of each party. By recording day-to-day occurrences of fatigue, a sleep contract enables an organization to know its actual fatigue risk and make informed decisions about fatigue risk management.

An ongoing education program for management and workers is essential and should consist of written material and on-site presentations and training, presented in the language(s) of the workers. The educational material should cover topics such as fatigue-related policies, standards and programs, adjustment to shift work and its effects, managing of fatigue, the impact of personal health on fatigue, and the importance of a healthy

lifestyle. It is also important to involve the families of shift workers. They should be provided with educational leaflets and advice concerning fatigue, the importance of sleep, sleep hygiene, and the nutrition, exercise and fatigue relationship. It is important to establish an employee assistance program to provide confidential, objective, and skilled assistance with solving work and nonwork fatigue-related problems. Medical personnel should be available to provide guidance to shift workers on the use of regular medication and health-related problems associated with shift work. Where appropriate, the employee assistance program may be extended to the families of shift workers.

Of fundamental importance is the requirement that the outcome of any fatigue management program should be able to be expressed in terms of meaningful parameters. All aspects of fatigue management should be reviewed at regular intervals to ensure continuing suitability, adequacy, and effectiveness of the controls for eliminating risk and also to identify new problems. Subjective and objective measures to achieve this objective include:

- Consultations with workers, supervisors, and health and safety representatives within formal and informal sessions
- Measuring levels of alertness and fatigue (Are workers continuing to experience fatigue?)
- Monitoring of incident reports and assessing the likelihood for fatigue contributing to incidents

To best manage fatigue, it is of cardinal importance to ensure that there is a process of ongoing monitoring and evaluation of workplace fatigue. This process should be regularly reviewed.

17.2.2.4 Measures of Success

The implementation of formal fatigue management procedures commenced in 2007. From a theoretical viewpoint reducing the risks associated with shift work and fatigue can improve the health and safety of workers, and may also financially benefit business and society in general by reducing sickness, injuries, and accidents, and by increasing work efficiency and product quality.

From a practical viewpoint, it is of fundamental importance that the outcome of any fatigue management program should be expressed in terms of meaningful parameters as measures of success, i.e., productivity, safety, and health. This aspect appears to be a weakness, not only in fatigue management in South African mines, but also in many established fatigue management programs elsewhere in the world (Health and Safety Executive, 2006). Practical and reliable measures of success are still being investigated, and important elements entail incident reporting formalities, data acquisition and analysis, and a system of review. From experience gained during the implementation of fatigue management at mines, it is evident that the following factors are crucial for success:

- Management and employee commitment (participatory approach)
- Accountability (Who is driving the process?)
- Proper hazard identification and risk assessment (consider all factors, work, and nonwork-related)
- Appropriate shift scheduling (assess risk using fatigue indices to evaluate shift systems)

- Sleep management (when and how to sleep as well as conditions conducive to restorative sleep)
- Identification of individuals at risk (risk-based medical examinations)
- Education and training (at all levels, including families of shift workers)
- Medical advice (especially for individuals with chronic medical conditions and those on medication)
- Ongoing monitoring and review (work-related indicators and feedback from employees)
- Fatigue management program must be site-specific

17.2.3 Managing Heat Stress in South African Mines

17.2.3.1 Problem Addressed

Occupational heat stress is a recognized health and safety hazard in South African mines. The consequences of high heat stress can be expressed in terms of impaired work capacity, errors of judgment with obvious implications for safety, and the occurrence of heat disorders, especially heatstroke which is often fatal (Donoghue et al., 2000; Kielblock, 2001; Brake and Bates, 2002; Kamilo and Nose, 2006; Taylor, 2006). The above scenario finds application in most of the deep level mines in South Africa.

Heat sources in underground mines can be divided into two broad categories, namely "natural" and "artificial." The former depends on the nature of the excavations and the rock strata, whereas the latter depends on the activities and operations of the mine (Kielblock, 2001). The mining of South African narrow tabular ore deposits at depths, such as those associated with some gold and platinum mines, presents unique challenges in providing acceptable thermal conditions to ensure safe and productive working environments. In these underground mines, the main source of natural heat is that transferred from broken rock. Virgin rock temperatures, which apply to unbroken rock, increase with depth and the geothermal gradient, i.e., the rate at which virgin rock temperature increases with depth, varies between 10°C/km and 22°C/km depending on the mining region. In the absence of artificial ventilation and cooling, the air temperatures in underground mines are generally close to the rock surface temperature (30°C to 60°C). Water is used extensively during mining operations and in combination with high air temperatures creates high humidity levels. Mining machinery and other electrically driven equipment also add to the environmental heat load. Heat stress is not only determined by environmental conditions, but is the net heat load to which a worker may be exposed from the combined contributions of environmental factors (i.e., air temperature, humidity, air movement, and radiant heat exchange) as well as the metabolic cost of work. The metabolic rates associated with conventional and mechanized mining in underground gold and platinum mines are, on average, of a moderately high intensity (130 to 180 W/m^2). While "hard work" (metabolic rate, 181 to 240 W/m^2) is performed, and is primarily associated with occupations directly involved with production. Very hard work (metabolic rate >240 W/m^2) is generally of short duration and is the exception rather than the rule (Van Rensburg et al., 1991).

17.2.3.2 Proposed Solution

Section 11 of the Mine Health and Safety Act (Act 29 of 1996) requires the employer to identify hazards, to assess the health and safety risks to which employees may be exposed

while they are at work, and to record the significant hazards identified and risk assessed. The employer must determine how the significant risks identified in the risk assessment process are dealt with. As far as it is reasonably practicable, attempts should first be made to eliminate the risk, thereafter to control the risk at source, then to minimize the risk and finally, insofar as the risk remains, to provide personal protective equipment and to institute a program to monitor the risk. Engineering strategies to counter occupational heat stress in an industrial setting usually involve reducing the environmental heat load (shielding, refrigeration, and increased airflow), to facilitate heat dissipation from the human body, and/or improved mechanization to minimize high metabolic rates. In the South African mining industry, technological and economic constraints often preclude a purely engineering-based approach. Personal protection and administrative controls then become the only viable alternatives.

The traditional approach to protect workers against heat stress in the South African mining industry was to acclimatize them to heat in climatic chambers before they were posted to hot work areas. However, in view of the specificity of heat acclimatization in terms of environmental temperature, work-rate and exposure time and the costly infrastructure required, as well as changes in legislation, an alternative approach was required to safeguard workers destined to work under hot conditions. The current Heat Stress Management Program (HSMP) is a multifaceted approach toward promoting health, safety, and work performance through minimizing human heat strain and the incidence of heat disorders. HSMP is in essence a risk management approach: it identifies potentially heat intolerant workers and removes them from the workforce and, through the implementation of countermeasures, strives to minimize the risk of developing heat disorders during work in the hot work environment (Schutte and Marx, 2007).

17.2.3.3 Programme Approach

The HSMP consists of two essential elements, namely the assessment of overall fitness to work in heat, and a natural progression toward heat acclimatization on the basis of safe-work practices. These two elements are to a large extent based on the etiology of heat stroke: the overall fitness for hot environments is measured against an individual employee risk profile (Kielblock, 2001) and the causal factors in the development of heat stroke in the mining industry are translated into safe-work practices.

17.2.3.3.1 Medical and Physical Examinations

The employee risk profile is based on the outcome of a purpose-designed medical examination, with special emphasis on features which would rule out physical work or exertion in heat, and the results of a heat tolerance assessment in a climatic chamber (Schutte et al., 1991). This profile consists of the following elements:

- Medical contraindications, i.e., a particular condition, treatment, or even a medical history likely to lead to a critical job-related reduction in heat tolerance
- Age (50 years and above) in concert with full-shift exposures to "strenuous" work in heat
- Obesity as measured by body mass index (BMI ≥ 30)
- Inherent heat intolerance
- Itrenuous work per se
- History of heat disorders

A risk profile that features not more than one of the above elements is generally regarded as "acceptable," while the presence of any two factors (elements) is viewed with concern and will not be condoned unless the situation can be improved, through, for example, specially developed safe-work practices. A profile containing more than two undesirable elements constitutes an unacceptable risk. The assessment of inherent heat tolerance is done by means of heat tolerance screening (HTS). The primary objective of HTS is to identify gross or inherent heat intolerance (i.e., individuals with an unacceptable risk of developing excessively high levels of hyperthermia during work in heat). The HTS used consists of bench stepping for 30 min in a climatic chamber at an external work rate of approximately 80 W (positive component), in an environment with a dry-bulb temperature of 29.5°C and a wet-bulb temperature of 28.0°C. The air movement in the climatic chamber is controlled within the range of 0.3 to 0.5 m/s (Kielblock and Schutte, 1998).

17.2.4 Safe-Work Practices

Within the context of the HSMP, no form of formal heat acclimatization will have preceded the allocation of employees to "hot" areas of work. Special precautions are therefore indicated, the rationale being based on the major causes of heat stroke in mining. A review of the occurrence of heat stroke (Kielblock, 1992) over a 10 year period identified "strenuous work" as the single most important causal factor, followed by suspect heat tolerance, dehydration, and excessively hot (dry-bulb >37.0°C, wet-bulb >32.5°C) thermal conditions. The author also found that the origin of heat stoke is multifactorial and in most instances resulted from an interaction between strenuous work, suspect heat tolerance, excessively hot environments, and concurrent dehydration. Excessively hot thermal environments constituted the most serious complication in the incidence of heat stroke fatalities. In fact, where such thermal conditions existed, the mortality rate was virtually doubled. On the basis of the findings of the review from Kielblock in 1992, a basic framework was derived for work practices in "hot" environments, irrespective of whether such heat loads are associated with surface, opencast, or underground operations. The safe-work practices that form part of heat stress management comprise:

- Monitoring workplace wet- and dry-bulb temperatures on a basis designed to ensure that safe limits are not exceeded and to detect the development of possible trends (Kielblock, 2007)
- Checking employees for overt signs of ill health or substance abuse, and removing such people from the place of work for attention appropriate to the situation
- Ensuring that acceptable work rates are maintained in order to avoid the early onset of fatigue (achieved through work–rest cycles (10 to 15 min rest in every hour) where work is of necessity strenuous and ongoing (e.g., drilling) or by instilling, through constant reminders, a sense of self-pacing)
- Ensuring that fluid-replacement beverages (preferably only water or hypotonic fluids) are available at the place of work and that a fluid-replacement regimen of at least 2 × 250–300 mL/h is observed
- Detection of early signs and symptoms of heat disorders and instituting proper remedial action depending on the precise set of signs and symptoms

- Ensuring that emergency treatment and communication facilities are available and fully functional on a daily basis
- Setting into motion purpose-developed emergency action plans in the event of sudden escalations in environmental temperatures

The above work practices, which should in any event be adopted as standard routine, are especially relevant to employees who return to work after a period of absence, irrespective of duration or reason. In this regard, it should be noted that some industries, such as American nuclear power plants, subscribe to a program of progressive exposure to achieve heat acclimatization, where for example the permissible exposure on the first day is limited to 50% of a full shift's exposure, and on successive days, respectively to 75% and 90% (Bernard et al., 1986).

17.2.4.1 Measures of Success

Heat has been a constant health hazard in South African gold (and more recently platinum) mines for more than 90 years; the problem cannot be resolved overnight and is likely to remain a potential hazard for some years to come. Measured against its objective, namely, the promotion of the health, well-being, and safety of all employees exposed to working conditions potentially conducive to heat disorders, heat stress management proved to be very successful. If statistics on the incidence of reportable heat disorders (heat stroke and heat exhaustion) is considered the implementation of heat stress management has contributed to a decline in heat disorders from 83 cases (21 heat strokes and 62 heat exhaustions) in the three year period before the general implementation of heat stress management in 1991, to 33 cases (five heat strokes and 28 heat exhaustions) for the period 2005 to 2007. This reduction was achieved through the elements that form the backbone of heat stress management: the detection of gross or permanent heat intolerance (approximately three per cent of the population assessed) and controlling the progression of "natural acclimatization on the job" which further reduces the risk of heat disorders.

17.2.5 Ergonomics of Mining Vehicle Design and Workspaces

17.2.5.1 Problem Addressed

Despite increasing levels of trackless mining automation in South African mines, there is a distinct lack of design focus specific to the human operator tasked with driving machines for prolonged periods of the work-shift. In many instances, the design of trackless mining equipment (TME) is poor, with improvised seating, poor cabin layouts and substandard display instrumentation.

The use of low profile (LP) and extra LP (XLP) mining machinery (see Figure 17.4) in narrow reef platinum mining operations is favored by mining houses in many instances for providing higher productivity. As with many industries, the mines implement new technologies as they are developed in an attempt to increase productivity and reduce costs (Steiner et al., 1998). LPs and XLPs are seen as a more productive alternative to traditional mining methods employed within platinum mines. However, these machines are not without potential risks to the operator and many potential hazards need to be assessed when the design of XLPs, either operator driven (in the instance of the long haul dump) or more recently fully radio-remote-controlled (drill rig, roof bolter, and dozer) is evaluated. This case study presents the findings of three preliminary investigations into the key risk

FIGURE 17.4
An example of the ELP machinery used in narrow reef mining operations.

factors associated with automated LP and XLP mining equipment currently in use in the South African platinum mining industry. The purpose of these studies was to quantify the current levels of vehicle safety and ergonomics application specific to cabin-driven mining machinery used in narrow reef platinum mining operations.

17.2.5.2 Program/Work Approach

The evaluation of TME design required physical and dimensional observations. Dimensional measurements and operator perceptual responses were taken during the HIRAs conducted in various underground mining environments. The field sample consisted of 21 operators (operators were selected from each of the four focus areas). These workers were "work-hardened" and appeared capable of meeting the physical demands the trackless mining tasks imposed on them. A number of observations were conducted to determine the different types of XLP machines currently in use. Underground observations of XLP machine operation were then conducted to allow for dimensional, task, and operator perceptual response analyses. The underground evaluations consisted of both objective and subjective analyses of the XLP working environment and attempted to estimate the current risk factors associated with extra LP mining. The specific problem focused on in this study was the design of XLPs with a view to providing basic guidelines to the manufacturers of remote-controlled units used in platinum mines. Dimensional evaluations were focused on the layout of the TME cabins and remote controls with a specific assessment of usability and fitness-for-use. Access, space, reach, and clearance were all considered in the mining equipment evaluation.

17.2.5.3 Operational Procedures

Operational procedures were assessed in four focus areas in the mines evaluated, and included: drill rig operation, roof bolting, dozing, and load haul dump (LHD) driving.

The assessment of perceptual responses is a useful method for gaining insight into workers' perceptions of the demands their current tasks make on them. Smith et al. (2002)

argued that the process of perceptual assessment is complementary to the dimensional evaluation and task analysis in identifying the aspects of XLP work that may be improved through ergonomics intervention. As part of this research, operators were questioned on their perceived levels of comfort while operating the XLF and were also asked to comment on the workspace, controls and displays, visual field, and their ability to communicate in their environment.

17.2.5.4 Proposed Solution

Research detailing the design flaws of TME has indicted that many of the problems are specific to positioning and access to the driver's cabin for the human operator. The preliminary studies assessing TME highlighted a number of task-related and design-related features (see Table 17.1) that may well benefit from ergonomics intervention, including:
XLP tasks

- Illumination of XLP equipment to enhance vision in the working environment
- Higher levels of personal hearing protection to protect the operator(s)
- Simple seating for the operator to be piloted

Equipment design

- Standardization of control coding and labelling to aid understanding of remote-controlled units
- Radio-remote-controlled unit to be used on the LHD (in progress)

Additional areas requiring ergonomics intervention

- Maintenance of control consoles to ensure that all levers and buttons are in good working order
- Alternate power sources to minimize (or eliminate) movement of the power cables
- Improved design of the XLP equipment to allow for easier maintenance

TABLE 17.1

Suggested Interventions for Improved Mining Equipment Safety

Ergonomics Intervention	Improved Health and Safety
Labelling of controls and displays	Reduce the number of errors and improve speed of activation
Forward visual access and illumination of XLP vehicles	Improve visual input and perceptual capabilities of operators
Communication and warning systems	Reduce margin for errors and warn miners of approaching XLPs
Seating	Reduce muscular fatigue and improve body support in the stope
General working posture	Reduce static muscular fatigue
Demarcation of hazard areas on the XLP machines	Reduce margin for errors and restrict operator from entering hazardous areas

17.2.6 Recommended Design Changes and "Low-Cost" Solutions

Low-stope mining poses a number of challenges to the worker with respect to the working posture adopted. The underground platinum mining environment is by nature not comfortable and the low-stope height necessitates a crouched or kneeling posture. It is strongly recommended that further investigation be conducted to assess the feasibility of a basic "extra low" seat for drill rig and dozer operators. Both operations require the operator to control the unit for extended period of time from the same position. A simple seat would eliminate the need for the operator to sit on wet and uneven ground. The seat would not carry large cost implications and could possibly be stored on the XLP for transporting. The operators should also be advised about how changing postures can minimize static fatigue. Roof bolting operators are required to frequently change postures and should therefore be provided with heavy-duty knee pads that increase the levels of protection, support, and comfort in the stope. The LHD should be equipped with a well-padded seat for the cabin-driven operations. Although the LHD will shortly be radio-remote-controlled in a number of operations, the cabin should still be designed according to sound ergonomics principles. The operator should be well supported by the seat and not be exposed to excessive levels of vibration in the cabin. The findings of the preliminary studies suggest that various aspects of XLP machine design and operation should be addressed (following basic intervention guidelines established by Smith et al., 2002). It is further recommended that the future design of XLP mining equipment incorporate consultation between the user (mine and operators) and manufacturer (equipment suppliers) in order that design, usability, and safety of equipment can be improved. The ergonomics interventions suggested above should be used as a basic guideline for ensuring that there is due compliance in terms of Section 21 (1)(c) of the Mine Health and Safety Act (Act 29 of 1996).

The hazards associated with XLP machines are largely related to a complex array of difficulties associated with low-stope mining. Although the design-related hazards identified placed the operators at risk, other areas of operation were greater sources of concern for underground mines, particularly the task of moving the cables used to power each of the electric trackless mining machines. During the tramming of the cable powered XLP equipment, operators are required to manually move the heavy machine power cables from one power source to another. These subtasks required high levels of physical exertion and should be further investigated to evaluate the hazards associated with these operations, and suitable ergonomic interventions proposed. It is strongly recommended that future designs of mining equipment be carried out with due consideration of the holistic principles of ergonomic, including anthropometric data, control positioning guidelines, and basic engineering guidelines for human operator use. At this time there are a number of pieces of mining equipment design which would substantially benefit from a revised approach to design based on sound ergonomics principles.

17.2.6.1 Future Challenges for the Mining Sector in Developing Regions

The mining sector in developing regions faces a number of challenges which require a clear focused approach. One of the major challenges is redesign and workplace modifications which accommodate the changing demographics of the mining population. The international trend of an aging workforce is also present in mining, and more women are involved in mining today than was the case in any previous generation. The latter point is particularly relevant in the artisan and small-scale mining sector, a sector that

has experienced significant growth worldwide, predominantly in remote rural areas of the developing world. Recent rises in the market prices of precious metals and stones, the main commodities mined on a small scale, have further fuelled this sector's rapid expansion. Employers have a legislative as well as moral responsibility to take all reasonably practicable steps to protect the occupational health and safety of their employees. Some of the characteristics of females and older workers may make them more vulnerable to certain types of occupational injuries, particularly in physically demanding work environments. Acknowledging and managing age and gender differences is important in order to implement strategies to reduce the risks within the mining industry. In this regard, the implementation of sound ergonomics principles can play an important role in reducing workplace hazards and improving work and job design that will benefit employees of both genders and all ages.

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18

Women in Indian Agriculture

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18.1 Introduction

Women in rural India play a major role in shaping the economy of the country. The female workforce in agriculture and allied sectors is estimated to be around 101 million, which amounts to about 42% of the total number of farm workers in the country. They participate in various production and postproduction agricultural operations including storage, packing, transport, and marketing. Besides their household management responsibilities, most of the work related to the management of cattle and other farm animals is also done by women. Studies have shown that Indian women work up to 14 h a day to carry out arduous activities on the farm and at home. While the modernization of agriculture is taking place at a fast pace, the jobs attended by women remain more or less the same. Though considerable work has been done to develop agriculture with a major emphasis on technical and economic achievement, very little attention has been given to gender issues. Technology development and transfer programs are generally carried out on the assumption that the technologies are either gender-neutral or that the men are the main users and decision makers (Castillo, 1985). This is often inappropriate as women have quite different technological needs than men due to different characteristics, level of education, experiences, and skills. Therefore, many of these programs prove to be ineffective as the technologies developed are not relevant to the needs of the women users, and transfer programs do not reach them.

18.2 Involvement of Women in Agriculture

In agriculture, women are required to carry out four different types of roles:

- As a worker (a source of power)
- As an operator (a controller)
- As a manager (a farmer)
- As an entrepreneur (a business person)

At present, most women have the role of workers only. Here, the rural women are usually employed to perform arduous field operations like sowing behind the plough, transplanting, weeding, harvesting and threshing, and primary processing of agro-produce. The activities in agro-processing involve cleaning, grading, drying, parboiling, milling, grinding, decortication (i.e., separating seeds from pods, seed coat), and storage (Singh et al., 2006). Women workers are also preferred in commercial agriculture like tea, coffee, sugarcane, cotton, tobacco, and plantation crops. Bidi making, jute retting, lack cultivation, processing and products preparation, cotton picking, sugarcane cleaning/detrashing, loading, spice picking, cleaning, and processing are also largely done by women. For some of these operations, hand tools and other equipment are available. Other operations are carried out by women using their hands and sometimes their feet. The tools and equipment available have been primarily developed for male workers, and female workers have to adapt to those whenever they use them. As a result, the output is lower and many occupational health problems also crop up. It also happens that the predominant jobs, which could be handled by women, are done by male workers using equipment, resulting in unemployment or underemployment for the female workers. Modern technology thus, if not given due consideration to upgrade the skill of women, may harm the women in long run, rather than benefiting them.

Very good reviews are available on women in agriculture (Prasad et al., 1988; Punia, 1991). However most of these studies were mainly related to employment pattern, wages, social issues, and the effect of modern technologies on these aspects. Technology as such has not received much attention. Srivastava et al. (1996) reported on technologies for enhancing employment opportunities for rural women. Jafry and O'Neill (2000) presented a review on application of ergonomics in rural development. Sulaiman et al. (2003) reviewed various ongoing programs being carried out on women in agriculture in India and gave suggestions for maximizing benefits from these programs.

18.3 Ergonomics

Ergonomics is the scientific study of the relationship between people and their working environments, which includes ambient conditions, tools and materials, methods of work, and organization of work (Figure 18.1). The efficacy of tools or equipment depends not only on the construction features, but also on the workers operating them. The performance of a human-implement system may be poor if ergonomics aspects are not given due attention. It may also cause clinical disorders thus affecting the workers' health. Proper attention to ergonomics aspects in design and operation will help in increasing human-implement system efficiency and also in safeguarding the workers' health.

18.4 Characteristics of Women Farm Workers

The following data are important for the suitable design of equipment and work methods:

- Anthropometric data
- Muscular strength

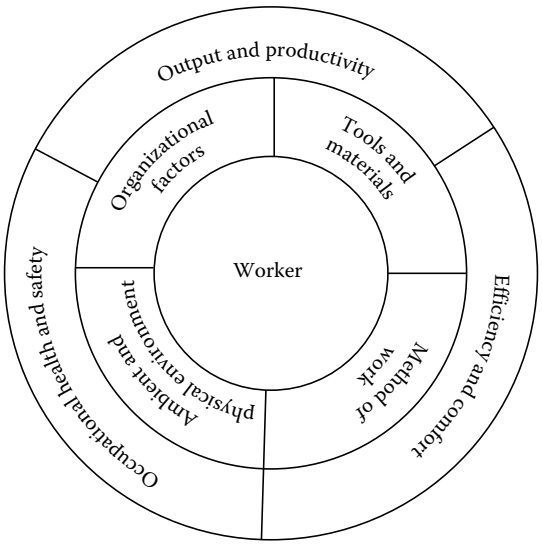

FIGURE 18.1
Ergonomics concept of equipment design.

- Maximum aerobic capacity
- Physiological cost of operation: heart rate (HR) and oxygen consumption rate (OCR)
- Posture
- Load-carrying capabilities

18.4.1 Anthropometric Data

This includes data on various body dimensions of workers. Gite and Majumder (2006) have identified 79 body dimensions which are useful for farm equipment design. They reported that the mean stature and mass of Indian male and female agricultural workers were 1630 mm and 53.8 kg, and 1512 mm and 45.9 kg, respectively, and that the overall results of the data on these dimensions clearly indicate that women have different work-related characteristics compared to men. Therefore, when designing and making equipment suitable for female workers, due attention needs to be given to match the basic design to their capabilities and limitations, when required to carry out the various operations. This will help to make the equipment female-friendly and safe for operation.

18.4.2 Muscular Strength

Gite and Majumder (2006) identified 16 strength parameters which are important in agricultural machinery design. These include hand-grip strength (right and left), push and pull strength with both hands in standing posture, push and pull strength in sitting posture (right and left hand), leg strength in sitting posture (right and left), foot strength in sitting posture (right and left), torque strength of preferred hand in standing posture, torque strength of both hands in standing (cranking) and sitting (steering) posture and hand-grip torque. The mean values of push strength with both hands in standing posture were 226 and 151 N for male and female workers, respectively (Gite and Majumder, 2006). It is generally acknowledged that women have about two-thirds the strength of men.

18.4.3 Maximum Aerobic Capacity

The maximum aerobic capacity (i.e., maximum OCR) sets the limit for maximum physical work capacity of a person. For women, this value is approximately 75% that of men. With the scanty data available for Indian workers, this value for women workers is about 1.5 l/min (Gite and Singh, 1997).

18.4.4 Physiological Cost

The physiological cost of any operation is usually expressed in terms of HR and/or OCR. For an 8 h work period for women workers, a workload requiring oxygen at a rate of 0.6 l/min is considered as the maximum limit for acceptable workload. The HR for such a workload is about 110–120 bt/min (ΔHR = 40 bt/min).

18.4.5 Posture

A good working posture is one which requires a minimum of static muscular effort. Under such conditions work performance will be better, and body discomfort less. Work that can be done in an upright posture instead of a stooped or squat posture is preferable,

particularly for long duration jobs; indeed for any long duration work, a sitting posture may be better than the standing posture. Any awkward posture will lead to body discomfort, or even pain, as will any excessive stress on the muscles due to the effort required to complete the activity. In many situations, though the work may be well within physiological tolerance, the musculoskeletal discomfort may restrict the duration of work depending upon the static load component involved; and this tends to be the case for most of the agricultural activities (Gite and Yadav, 1990; O'Neill, 2004).

The psychophysical scales used for assessing overall discomfort include Borg's Rating of Perceived Exertion (1970) (6–20 scale), Corlett and Bishop Body Discomfort (1976) (0–7 scale), and Visual Analogue Discomfort scale (0–10 point scale) (Legg and Mahanty, 1985). For the Indian situation the visual analogue discomfort scale was found to be most suitable as the workers are familiar with the decimal system. For assessing body part discomfort, the technique suggested by Corlett and Bishop (1976) is commonly used.

18.4.6 Load-Carrying Capability

Many of our agricultural operations involve load-carrying activities. It is generally considered that the load to be carried by a worker should not exceed 40% of body weight (Kinoshita, 1985). The mode of load carrying should be such that long duration static loading of hands and arms is avoided.

18.5 Drudgery Assessment in Agricultural Operations

For many farm operations, hand tools and equipment are available, while others are carried out manually by women workers. When assessing the physical strain experienced in this form of manual labor, the common parameters used are given below:

- Working HR (WHR), beats/min
- ΔHR, bt/min (increase in HR over rest)
- OCR, l/min
- ΔOCR, l/min (increase in OCR over rest)
- Energy expenditure rate (EER), kJ/min
- ΔEER, kJ/min
- Overall discomfort rating (ODR)
- Body part discomfort score (BPDS)

18.5.1 Drudgery Involved in Operation per Unit Time

This can be assessed using the first six parameters, namely WHR, ΔHR, OCR, ΔOCR, EER, and ΔEER per unit time, and the lower the value of these parameters, the less drudgery will be involved in the operation of that equipment. Of these parameters, WHR and OCR are measured, and the remaining four are calculated from these two. For calculation of EER from HR, the Varghese et al. (1994) equation can be used which is as follows:

$$\text{EER (kJ/min)} = 0.159 \times \text{HR (bt/min)} - 8.72.$$

For calculation of EER from OCR, the calorific value of oxygen can be taken as 20.9 kJ/l of oxygen.

18.5.2 Drudgery Involved in Operation per Unit Area or per Unit Output

Generally, improved tools and equipment have the effect of raising work capacity. So to take care of that aspect, the extra heartbeats elicited, the extra oxygen consumed, and the energy expended over their resting values per unit output are calculated for comparison. Lower values signal better conditions. However, while doing this exercise, one has to keep the values for WHR, OCR, and EER within the acceptable limits. Otherwise, the workers will have to take more frequent rest pauses to sustain their efforts for the day.

18.5.3 Discomfort Rating

Lower discomfort ratings signal better tools, equipment and/or work methods. However, the discomfort experienced is the cumulative effect over time, and for this purpose the work bout also needs to be considered.

18.5.4 Improved Tools and Equipment for Women Workers

As mentioned above improved hand tools and equipment help to achieve one or more of the following:

- Reduce drudgery
- Increase utilization efficiency of inputs
- Ensure timeliness in field operations and reduce turn around time for next crop
- Increase productivity of worker–machine system
- Conserve energy
- Improve quality of work and also quality of produce
- Enhance the quality of work life of agricultural workers

More than 50 improved hand tools and manually operated equipment items have been developed by various research organizations in the country. Of these, 21 have been ergonomically evaluated at CIAE/NRCWA subcenter/SAUs and were found to be suitable for women workers (Singh et al., 2007). These can suitably be commercially manufactured and then made available to farm women in order to reduce drudgery and enhanced output. Brief information on these tools and equipment items is presented in Table 18.1.

18.6 Training

Technology development will invariably be followed by commercialization, awareness, and infrastructural support. In the present scenario of fast growth and development in all spheres of science and technology, it is essential to transfer the technologies to the end users in the most effective way. This is more relevant when the technology involves tools and equipment where training in operation, repair, and maintenance are essential particularly to strengthen service support. Due to sociocultural inhibitions, rural

TABLE 18.1

Improved Tools and Equipment Suitable for Women Workers

Sl. No.	Operation	Traditional Practice	Improved Tool/Equipment and Details	Remarks
1	Seed treatment	Done with bare hands Nonuniform application, possible seed damage, health hazards—chemicals in direct contact with hands	Seed treatment drum Cost—Rs. 1400/-, capacity—200 kg/h, contact with chemical avoided, uniform application, no seed damage	Commercially available
2	Ridge making	With spade in bending posture, output—80 m^2/h, discomfort due to bending posture	Hand ridger Cost—Rs. 400/-, capacity—330 m^2/h, bending posture is avoided, discomfort is reduced during operation, about 67% saving of cardiac cost of worker per unit area	CIAE design
3	Fertilizer broadcasting	Broadcasting by hand, output—0.31 ha/h, nonuniform distribution, problem due to direct contact of fertilizer with hands	Fertilizer broadcaster Cost—Rs. 1000/-, capacity—1.15 ha/h, uniform application, no direct contact of fertilizer with hands, about 6% saving of cardiac cost of worker per unit area	Commercial units refined at CIAE and TNAU. One manufacturer is making this equipment
4	Sowing	Broadcasting seeds by hand or by putting the seeds manually in row after opening the furrow with hand hoe, output—20 m^2/h	Manual seed drills Cost-Rs. 1500/-, capacity—430 m^2/h, row sowing possible, about 87% saving of cardiac cost of worker per unit area	PAU and CIAE designs
5	Dibbling	By hand in bending posture, output—120 m^2/h	Naveen dibler Cost-Rs. 335/-, capacity—150 m^2/h, bending is avoided, about 13% saving of cardiac cost of worker per unit area	CIAE design
			Rotary dibler Cost—Rs. 1200/-, capacity—1060 m^2/h	CIAE design
6	Rice transplanting	By hand in bending posture, output—34 m^2/h	Two row rice transplanter Cost—Rs. 5000/-, capacity—61 m^2/h, bending avoided, about 13% saving of cardiac cost of worker per unit area	CRRI design
			Four row rice transplanter Cost—Rs. 6000/-, capacity—135 m^2/h, bending avoided, about 61% saving of cardiac cost of worker per unit area	

(*continued*)

TABLE 18.1 (continued)

Improved Tools and Equipment Suitable for Women Workers

Sl. No.	Operation	Traditional Practice	Improved Tool/Equipment and Details	Remarks
7	Rice seeding	Broadcasting by hand, nonuniform sowing, difficulty in weeding	Four row paddy drum seeder Cost—Rs. 3000/-, capacity—920 m^2/h, uniform seeding in rows	TNAU design
8	Weeding in dry land	Hand hoe, capacity—45 m^2/h, in squatting posture	Wheel hoe Cost—Rs. 300/-, capacity—150 m^2/h, squatting and bending avoided, about 45% saving of cardiac cost of worker per unit area	CIAE design
9	Weeding in wet land	By hand in bending posture, capacity—30 m^2/h	Cono weeder Cost—Rs. 700/-, capacity—120 m^2/h, bending is avoided	TNAU design
10	Harvesting	Local sickle, capacity—150 m^2/h for wheat, weight—350 gm, higher fatigue	Improved sickle Cost—Rs. 40/-, capacity—150 m^2/h for wheat, weight—180 g, less fatigue due to lower weight and serrated edge, about 15% saving of cardiac cost of worker per unit area	CIAE design
11	Groundnut stripping	By hand beating on rods, damage to pods	Groundnut stripper Cost—Rs. 700/-, capacity—11 kg/h/person, four persons can work at a time, muscular discomfort reduced as work is done in sitting posture and the arm is not to be lifted above shoulder as in case of traditional practice	TNAU design
12	Paddy threshing	By hand beating in bending posture	Pedal operated paddy thresher Cost—Rs. 2500/-, capacity—35 kg/h, discomfort is reduced as work is done in standing posture	OUAT design
13	Maize shelling	Local sickle, capacity—17 kg/h, possibility of injury to fingers	Tubular maize sheller Cost—Rs. 30/-, capacity—27 kg/h, safe operation in sitting posture, less discomfort, about 15% saving of cardiac cost of worker per unit output	CIAE design

TABLE 18.1 (continued)

Improved Tools and Equipment Suitable for Women Workers

Sl. No.	Operation	Traditional Practice	Improved Tool/Equipment and Details	Remarks
			Rotary maize sheller Cost—Rs. 4500/-, capacity—73 kg/h, operation in standing posture	Commercially available
14	Grain cleaning	By hand with supa, capacity—25 kg/h	Hanging type grain cleaner Cost—Rs. 2500/-, capacity—225 kg/h, about 63% saving of cardiac cost of worker per unit area	CIAE design
15	Groundnut decortication	By hand, capacity—1 kg/h, abrasion and injury to fingers	Sitting type groundnut decorticator Cost—Rs. 750/-, capacity—30 kg/h, work done in sitting posture, less discomfort, about 79% saving of cardiac cost of worker per unit output	CIAE design CIAE design
			Standing type groundnut decorticator Cost—Rs. 900/-, capacity—40 kg/h, about 74% saving of cardiac cost of worker per unit output	
16	Fruit harvesting	By hand picking, possibility of accidents and injury	Fruit harvester Cost—Rs. 110/-, capacity—420 fruits/h for sapota	KKV design refined at TNAU
17	Cotton stalk uprooting	By hand pulling in bending posture	Cotton stalk puller Cost—Rs. 700/-, capacity—280 m^2/h, discomfort and probability of back injury is reduced as work is done in standing posture	Commercially available

women workers seldom volunteer to operate mechanical equipment in the field. Even in handling simple hand tools, they have reservations. If urban women can operate machines, there is no reason why rural women should not be encouraged to operate agricultural equipment. It only requires infrastructure and facilities to train them at places which are within their reach. This may be accomplished either by training them in their own environment or by bringing them to training centers located in close proximity. This will help in the upgrading of skill for the women, enabling them to operate various agricultural tools and equipment.

18.7 Extension Services

It is important to ensure better access for these farm women to the various aspects (including farm tools and equipment) needed by them to carry out their work more efficiently and with minimal drudgery, but it must be noted that they have little access to nonformal education and training. It is a fact that agricultural extension services are mainly composed of male agents and as such they tend to channel knowledge and training on improved technology to male farmers/workers only. There is also a lack of infrastructural facilities for women in relation to technical training, accommodation, and transport provision. It is imperative that central/state government departments, R&D institutions, and NGOs promote improved technology to enhance the labor productivity of women workers and to reduce their drudgery. They should also recruit women extension staff in their extension wings for effective transfer of women-specific technologies to farm women.

18.7.1 Availability of Improved Tools in Rural Areas

The state agricultural departments and State Agro Industrial Development Corporations may have to take the leading role because agricultural machinery is under the control of state governments. The supply of improved tools and equipment need to be ensured at block/village level so that there is assured availability to farm women as per their requirement.

18.8 Occupational Health Hazards of Women Workers

Occupational health hazards these women workers have to face can be broadly categorized in three groups, namely health hazards in farming activities, health hazards in agricultural processing industries, and health hazards in domestic activities, and these are briefly explained here.

18.8.1 Health Hazards in Farming Activities

18.8.1.1 Health Hazards due to Physical Workload

Women are usually employed in various arduous field operations. Given their different physical characteristics, the operation of most tools and equipment results in severe physiological stress placed on women workers. High musculoskeletal loads and excessive spinal loading due to awkward postures are other features in farm work associated with the long duration of work bouts (Nag, 1998). All these result in various clinical disorders with symptoms including backache, muscle pain, and weight loss. Consideration of the capabilities and limitations of women workers while designing tools, implements, and the various operations which have to be done can help in minimizing these health hazards.

18.8.1.2 Health Hazards due to Extreme Ambient Conditions

Farm women have to work during heavy downpours in the monsoon season in operations like rice transplanting. In winter it is extremely cold, whereas during summer the extreme

hot weather can cause sunstroke. As most farming activities are carried out in fields, provision of rainwear in the monsoon period, warm clothing in winter, and sun caps in summer can help to reduce the weather hazards. A change of work hours in summer, i.e., working mornings only or in the morning and evening can also help to minimize the exposure of the workers to extreme heat.

18.8.1.3 Health Hazards in Pesticide Application

According to a WHO (1990) report, there are about 3 million severe pesticide poisoning cases on a global level every year, of which 2 million cases are suicidal, 0.7 million cases are occupational accidents, and 0.3 million cases are nonoccupational accidents resulting in the death of about 0.3 million people. In India, pesticide poisoning has also increased to alarming proportions. Women workers are mostly involved in the preparation of pesticide mixtures with water and pouring the mixture into sprayers. In some regions, they also carry out the actual spraying operations. Treating the seeds with chemicals is also mainly done by women workers. In these operations, contact of pesticides with skin and eyes is common and causes irritations besides other clinical problems. Inhalation of pesticide fumes/spray/dust also results in dizziness, headache, and other health disorders. Use of personal protective wear which include gloves, face masks, and goggles can help to reduce the health hazards caused by working with these pesticides.

18.8.1.4 Health Hazards in Tobacco Cultivation

There are about 0.7 million workers engaged in growing of tobacco in the country. Ghosh et al. (1998) reported "green tobacco sickness" as the occupational health problem associated with tobacco harvesting. It is characterized by headache, nausea, vomiting, giddiness, and weakness. It is observed that during handling of green tobacco leaves in the field, the nicotine gets absorbed through skin and causes these symptoms. Use of gloves would help to reduce the "green tobacco sickness" besides reducing the multiple aberrations of palmer surface.

18.8.1.5 Health Hazards in Various Field Operations

While carrying out various agricultural activities such as transplanting, weeding, harvesting, soil handling, threshing and winnowing the women workers get abrasions, lacerations or injuries on different parts of the body, particularly on the legs, feet and hands, by objects like splinters, thorns, sticks or hand tools and equipment. Fungal and bacterial infections may enter through the injury point and cause infection and sickness. Immediate attention to cuts, lacerations, and abrasions on the skin, and dressing the wound with antiseptic and timely medical treatment can help in minimizing these health hazards.

18.8.1.6 Health Hazards in Livestock Farming

Agricultural workers are at higher risks of acquiring zoonotic diseases because of the close link between agriculture and animal husbandry. About 40 zoonotic diseases have been recognized as occupational diseases in global agriculture. Workers may acquire a zoonotic disease through:

- Direct contact with diseased animals or infected materials
- Consumption of contaminated water, milk, etc.
- Inhalation of infectious organisms
- Vectors (germs carrying insects)
- Accidental inoculation of pathogen through breach on skin

In India, women are actively involved in carrying out various operations related to animal handling and they frequently come in to contact with animals. Leptospirosis is one of the widely prevalent zoonotic infections transmitted from animal to human being. The workers contract infection by direct exposure to the urine of the infected animals or to an environment contaminated with urine, blood, or tissues of infected animals. Gandhi (1998) mentioned that there were outbreaks of leptospirosis continuously for four years during the monsoon season in Gujarat state. The symptoms associated with this disease are fever and myalgia. Health education, particularly to occupationally exposed people in endemic areas, about modes of transmission, avoidance of use of contaminated sources of water, and need of protective devices can help to minimize these hazards.

18.8.1.7 Health Hazards in Silk Grainages

Silk grainages are the seed (egg) producing centers breeding the silkworm moths which emerge out of cocoons preserved for the purpose. The silk grainages are concentrated in Karnataka and Bihar. The health hazard here is mainly due to dust resulting from the scales of wings of silkworm moths. Krishnamurthy et al. (1998) measured the dust concentrations using personal air sampled in the work space in grainages and reported the mean value as 4.4 mg/m^3. They recommended that the grainages should be provided sufficient ventilation to reduce the dust concentration. Provision of filter pad respirators to the workers was also suggested to minimize the health hazards.

18.8.2 Health Hazards in Agricultural Processing Industries

18.8.2.1 Health Hazards due to Dust

Almost all postharvest and processing activities are performed by women. The operations include cleaning, grading, drying, parboiling, milling, grinding, decortication, ginning, and storage. In these operations, there is a great deal of dust in the working environment and it constitutes a major health hazard to workers. Kotwaliwale and Sahay (2007) reported that the dust content in Dal mills (pulse processing industries) was as high as 490 mg/m^3 of air, i.e., about 50 times the permissible limit. A similar situation exists in flour mills. In cotton gins also, the dust content in the work environment is very high. Therefore, workers in agricultural processing industries are subjected to frequent throat infections/bronchitis/respiratory health problems. Proper layout of the mill/ginning unit, selection of good quality machines, and provision of sufficient ventilation can help to bring down the dust content in the working zone. Provision of face mask/respirators to the workers will protect them from the dust in unavoidable situations.

18.8.2.2 Health Hazards due to Noise

Noise is also a stress agent which causes health problems for workers. Continuous exposure of workers to noisy machines causes hearing problems. As per the national, as well as international standards, the noise levels in the working environment should not exceed 90 dB for an 8 h work duration. However, in many of the agricultural processing plants, the noise levels can be as high as 98 dB in the working zone. Selection of proper machinery for a processing unit, and its proper layout and installation can help in reducing the noise levels in the environment. In unavoidable situations, the workers may be provided with earmuffs to protect them from excessive noise and/or the work time can be reduced to limit the noise exposure.

18.8.3 Health Hazards in Domestic Activities

All household activities, including gathering of fuelwood, fetching of water, food processing, cooking, dairying, washing, childcare, and utensil cleaning are performed by women. Searching for fuelwood and carrying it on one's head is very common in rural areas and it consumes a lot of energy of women workers. It also results in musculoskeletal stresses causing back pain. Fetching water from wells or via hand pumps is another operation which involves a lot of drudgery. At many places, the handle of hand pump is placed so high that the pump has to be operated at shoulder level causing arm ailments. Sometimes the force required in handle operation of the pump is so great that it causes muscular discomfort. Selection of a good hand pump and its proper installation helps to reduce the health hazards associated with water pumping.

Some studies have been carried out at the SNDT University of Mumbai on women workers and their relationship with the home environment including various kitchen gadgets, tools, and equipment (Varghese, 1993). It was observed that cooking activities done in a sitting posture were less tiring than at a standing posture. It is recommended that a combination of sitting/squatting and standing postures may be adopted so as to minimize the work stress in kitchen activities. Regarding floor cleaning activities of sweeping and mopping, it was observed that long handled brooms and mops were better than the traditional ones in terms of physiological cost.

Wood and coal are extensively used for cooking and heating activities in rural India. This is a major source of indoor air pollution causing health hazards to women. It is generally observed that while using a local wood stove (traditional chullah) the carbon monoxide (CO) levels in the vicinity of women workers are very high, 200 ppm and more. Exposure to such high levels of CO for hours is very hazardous for women working in the kitchen. The thermal efficiency of the traditional chullahs is also about 7%–8% only. The particulate emissions produced in such chullahs are also very high. The smoke generated during wood burning causes irritation to the eyes and choking in the throat. The improved wood stove designed at many places (including at CIAE Bhopal) can give thermal efficiency of about 20% and the emission level of CO in the vicinity is below 5 ppm. In addition to improved cooking stoves, adoption of new gadgets and sources such as solar cookers and biogas can help in minimizing health hazards in kitchen activities.

18.9 Future Strategy for Technology Development and Promotion

In the changing scenario of modern India, the female workforce in agriculture is likely to increase to 55% by 2025 so that, out of the total estimated agricultural workforce

of 242 million, about 133 million will be women workers. This is expected to happen mainly because male workers are likely to get involved in nonfarm activities or migrate to towns and cities for other jobs. To meet this situation, it will be necessary to take the following steps:

1. Design/redesign of equipment keeping in view the anthropometric and strength data of women workers, to make it worker friendly and safe for operation.
2. Impart training to rural women on the proper and safe operation of various modern tools and equipment. This will help in reducing the drudgery, and increasing productivity.
3. Make the tools and equipment available at village level for purchase/hire by women workers.
4. Assist farm women, after being duly trained to get loans from banks and other organizations to procure various tools and equipment, or to set up agricultural processing centers. This will help them in reducing their drudgery apart from getting gainful employment for income generation. Continuous follow-up is needed to make this program a success.
5. Develop a countrywide action plan involving agricultural engineers and home scientists, and Government Departments of Agriculture. Such a program will help to improve the availability and adoption of ergonomically improved tools and equipment substantially.

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19

Ergonomics in Construction, Specifically in Industrially Developing Countries

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19.1 Introduction

According to Marmaras et al. (1999), while the science of ergonomics is a relatively recent phenomenon, there is evidence to suggest that ergonomics principles were known to the ancient Greeks. The word "ergonomics" is derived from two Greek words "ergon," meaning work, and "nomos," meaning laws. Today, however, the word is used to describe the science of "designing the job to fit the worker, not forcing the worker to fit the job" (Kroemer and Grandjean, 1997); thus it is the science of adapting work and working conditions to suit the worker.

Ergonomics combines knowledge of human abilities with that of tool design, equipment, and work organization. According to Monk (2005), occupational ergonomics has to do with the design or modification of the workplace and the organization of work to match the worker. The aim of occupational ergonomics is to decrease injuries at the workplace and to improve productivity. Ergonomics principles can be applied at many stages of work design. They can be used in tool and equipment design, workplace layout, and the planning of work processes.

Schneider and Susi (1994) maintain that construction, by its very nature, is a problem for ergonomists as it requires work above shoulder level and below knee height. Materials may also be heavy and/or inconveniently sized and shaped, thus presenting manual materials handling problems. According to Gibbons and Hecker (1999), numerous construction tasks pose significant risks to workers. The aim of this chapter is to consider the importance of ergonomics to the construction industry, as well as to identify work risks in construction, and point out the impact of even minimal ergonomics on the construction process. The chapter discusses the aspects which negatively affect the workers, and the interventions required in order to improve ergonomics in construction work processes.

19.2 Nature of Construction-Site Problems

Vedder and Carey (2003) contend the following are the most important safety, health, and ergonomically related problems in construction: accidents with construction tools; falling and tripping; manual handling, lifting, and carrying; noise; vibration; dust exposure; and poor design of tool interfaces. The University of Iowa (Center to Protect Workers Rights 1995) consulted approximately 2000 construction workers in the United States to determine where they hurt and the reason why. Of the job factors which constituted major ergonomically related problems, the following were the top four:

- Bending or twisting the back
- Staying in the same position for long periods
- Working in the same position for long periods
- Handling heavy materials or equipment

Research conducted among construction workers representing six trades in the United States investigated inter alia, the extent to which 15 job factors constituted a problem on a scale of: minor-problem, minor–moderate problem, and major problem. Based upon a score out of 10, the following were determined to be the top five work-site problems resulting from little or no ergonomics input: working in the same position for long periods (5.7), bending or twisting the back in an awkward way (5.5), working in awkward or cramped positions (5.0), working when injured or hurt (4.7), and handling heavy materials or equipment (4.6) (Zimmerman et al., 1997).

A series of research studies conducted in South Africa investigated, inter alia, the frequency at which work problems were encountered (Smallwood 1997; Smallwood et al. 2000; Smallwood 2002). The problems are ranked in Table 19.1 based upon an importance index (II) with a minimum value of 0.0, and a maximum value of 4.0, which in turn was based upon percentage responses to a range "never" to "daily." The findings emanating from four sample strata surveyed during three studies are presented. The first study, which entailed the survey of both general contractors (GCs) and workers, was undertaken in 1997, the second study which entailed the survey of solely workers was undertaken in 2000, and the third study, which entailed the survey of "better practice" health and safety general contractors (BPGCs) was undertaken in 2002. An overall mean II, computed from the four sample strata, is also presented. It is notable that handling heavy materials, which achieved a ranking of third in South Africa, achieved a ranking of fourth and fifth in the respective U.S. studies. Although the other respective top four ranked problems were not

TABLE 19.1

Frequency of Ergonomic Problems Encountered in South African Construction According to Management and Workers (II = 0–4)

	GC (Smallwood, 1997)		Worker (Smallwood, 1997)		Worker (Smallwood et al. 2000)		BPGC (Smallwood, 2002)		Mean	
Problem	**II**	**Rank**	**II**	**Rank**	**II**	**Rank**	**II**	**Rank**	**II**	**Rank**
Repetitive movements	3.29	1	3.56	1	2.97	3	3.78	1	3.40	1
Climbing and descending	2.88	2	3.01	4	3.23	1	3.56	2	3.17	2
Handling heavy materials	2.63	4 =	2.68	10 =	3.00	2	3.44	3	2.94	3
Use of body force	2.80	3	2.82	8	2.77	5	3.00	9	2.85	4
Exposure to noise	2.53	7	2.93	6	2.65	6	3.11	6 =	2.81	5
Bending or twisting the back	1.96	11	3.47	2	2.38	7	3.22	4 =	2.76	6
Reaching overhead	2.61	6	2.99	5	2.00	13	3.11	6 =	2.68	7
Reaching away from the body	2.41	8	3.19	3	2.03	12	2.63	12	2.57	8
Working in awkward positions	1.70	12	2.85	7	2.30	9	3.22	4 =	2.52	9
Handling heavy equipment	2.03	10	2.17	13	2.87	4	2.78	10	2.46	10
Working in hot conditions	2.29	9	2.68	10 =	2.15	10	2.33	13	2.36	11
Vibrating tools and equipment	2.63	4 =	1.43	16	1.96	14	3.11	6 =	2.28	12
Working in cramped positions	1.46	15	2.48	12	2.13	11	2.67	11	2.19	13
Staying in the same position for long periods	1.29	17	2.76	9	2.30	8	2.11	14	2.12	14
Working in humid conditions	1.60	13	1.53	15	1.66	17	1.89	15	1.67	15
Working in cold conditions	1.38	16	1.80	14	1.85	15	1.22	17	1.56	16
Working in wet conditions	1.57	14	1.21	17	1.70	16	1.67	16	1.54	17
Working while injured or hurt	0.19	18	0.84	18	0.48	18	0.44	18	0.49	18

Sources: Adapted from Smallwood, J.J., *Ergonomics SA* 9(1), 6, 1997; Smallwood, J.J., Deacon, C.H., and Venter. D.J.L., *Ergonomics SA* 12(1), 2, 2000; Smallwood, J.J., *Ergonomics SA* 14(1), 8, 2002.

TABLE 19.2

Causes of Nontraumatic Injuries Relative to Age

	Causes of Nontraumatic Injuries												
	Repetitive		Awkward Posture		Fixed Posture		Heavy		No Breaks		Other		Total
Age	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
<20	4	28.6	4	28.6	0	0.0	3	21.4	3	21.4	0	0.0	14
20–30	17	41.5	11	26.8	4	9.8	4	9.8	3	7.3	2	4.9	41
30–40	15	28.9	10	19.2	9	17.3	9	17.3	6	11.5	3	5.8	52
40–50	12	25.0	12	25.0	4	8.3	9	18.8	6	12.5	5	10.4	48
Total	48	31.0	37	23.9	17	11.0	25	16.1	18	11.6	10	6.5	155

Source: Ramana, K.R. and Satyanarayana, K.N., *Proceedings of the 4th Triennial International Conference Rethinking and Revitalising Construction Safety Health Environment and Quality,* pp. 461–469, Port Elizabeth, South Africa, May 17–20, 2005. With permission.

common to both South Africa and the United States, bending or twisting the back, which achieved a ranking of second in the United States, achieved a ranking of sixth in South Africa. Furthermore, in terms of the top ranked South African problems, the following should be noted: repetitive movements are more likely in a country such as South Africa, which makes predominant use of masonry materials for walls, than a country that makes use of prefabricated framing and panels such as the United States. Climbing and descending are more likely in a country which makes limited use, if any, of vertical transportation of people as with personnel hoists, than in a country that does.

More recent trade-specific research conducted in the Western Cape, South Africa, among bricklayers, plasterers, painters, and their respective assistants, identified neglected ergonomics issues (Samuels et al., 2006). The problems include: bending and twisting of the body; reaching away from the body and reaching overhead; working in awkward positions; lifting and manually handling heavy and irregularly sized and shaped materials and components; working below knee level; and working while kneeling. Most of these activities also involved working at extreme ranges in challenging environments. A study conducted in Hyderabad, India by Ramana and Satyanarayana (2005) identified the causes of nontraumatic injuries, where repetitive movements predominated, followed by awkward postures (see Table 19.2).

19.3 Trade-Related Problems and Ergonomics Solutions: A Case Study

Schneider and Susi (1994) reviewed the findings of a team of industrial hygienists who followed the construction of a four-storey office building for the 15 months duration of the project. In relation to the various trades, the following examples are a summary and provide an indication of the work hazards which result from the construction process and possible poor design, together with the ergonomics-related solutions (in italics) which mitigate or eliminate the hazard.

Concreting: Shoveling and smoothing the surface of concrete are strenuous on the lower back.

The addition of plasticizers improves concrete workability.

Reinforcing: The fixing and tying of bar reinforcing which requires bending and a great deal of rapid repetitive twisting of the wrist, the latter resulting in the development of ganglion cysts.

The use of fabric, in lieu of bar reinforcing, reduces the amount of time spent fixing and tying reinforcing per concrete element, and the amount of bending and rapid repetitive twisting of the wrist. Using trestles also enables steel fixers to fix cages at "worktop" level.

Formwork: The erection and striking of support-work and form-work require a large amount of bending, twisting, and use of body force.

Designers can facilitate the use of composite systems through the simplification of design, table forms, and wall forms which can be handled by cranage, thereby reducing the manual aspect of an activity. The use of precast concrete also reduces the amount of support-work and form-work, and on-site fixing and tying of reinforcing required. Prestressed concrete elements, particularly slabs, also reduce the amount of bar reinforcing.

Structural steelwork: Problems associated with the erection thereof include awkward postures, occasional high force requirements, static postures, repetitive movements, use of pneumatic tools, and lifting. The high risk nature of the activity which entails straddling beams several meters in the air while aligning and bolting together columns and beams compounds the problems.

Preassembly, simplified joints, and integral safety features can reduce the hazards.

Masonry: Block and brick laying represent major work hazards in building. Lifting an average of 1000 bricks a day is the equivalent to lifting 2300–4000 kg, and 1000 trunk-twist flexions.

A construction-related intervention includes the provision of waist high materials platforms. Design improvements include the incorporation of hand-holds in blocks to facilitate lifting. Alternative wall systems constitute the optimum solution.

Roofing: Roofing poses many different hazards due to minimal ergonomic input, but the prime one is materials handling. Of the three types of roofing, unit and sheet materials and waterproofing membranes, unit materials require considerably more bending, twisting, and handling of mass per square meter of covered area, than sheet materials.

The use of "ladder type" tile lifts facilitates the lifting of unit materials to roof level.

Building fabric: Differing systems and materials pose differing problems. Concrete surface finishes such as bush-hammering present a risk of hand-arm vibration and health problems such as silicosis. Natural stone claddings require a lot of lifting and hoisting of panels, adopting of awkward postures and hand-arm vibration as a result of fixing, presenting a risk of back injury and hand/wrist problems.

Design alternatives include light weight sheet metal claddings and curtain walling, which will minimize the risk factors.

Plumbing and drainage/pipefitting: Piping is often at odd angles and in cramped spaces. Specific piping materials have specific jointing methods, not all of which are complementary to basic ergonomics principles. A number of installations are suspended and require extensive overhead work, the fixing of the suspension hangers resulting in substantial stretching and twisting, and consequently a high level of stress on the neck and shoulders of workers.

Designers should consider the ergonomic implications of jointing methods when specifying materials, the feasibility of prefabricated stacks, and horizontal and vertical service ducts for piping.

Electrical: Electricians often work in cramped postures and their work entails a large amount of wrist action resulting in stress on the arm and shoulders. Making connections requires extensive use of hand-tools, often in cramped spaces such as ceilings above and between ducting and other piping.

Designers should make adequate provision for access during both design and coordination of services during design.

Floor finishes: All floor finishes require constant kneeling and bending. Ceramic and similar tile and terrazzo work entail additional risk. Often the weight of the tiles to be set can be substantial, particularly in the case of natural stone. Terrazzo and similar finishes require considerable hand and wrist motion.

When specifying finishes, designers should consider the nature of processes pertaining thereto. Using trestle type work benches reduces the need for tilers to cut at floor level.

Suspended ceilings: Most suspended ceilings require significant overhead work although the components are not particularly heavy. It is necessary to suspend primary tracks from hangers and secondary tracks between the primary tracks. Screw-up suspended ceilings require considerably more overhead work than lay-in tile ceilings.

Consequently, designers should specify the latter where possible. The use of mobile tower scaffolds with full work platforms is more complementary to ergonomics than the use of ladders.

Painting and decorating: Overhead painting of ceilings places considerable stress on the arms and shoulders, as well as the neck.

Designers should consider self-finishes where possible.

Paving and other external work: Brick paving requires work similar to that of tiling. In addition, pavers often have to be cut with an electrically powered masonry saw which requires working at ground level, and consequently requires the workers to bend a great deal.

The use of work-bench type masonry saws does reduce the hazard. Although asphalt paving exposes workers to whole-body and hand-arm vibration, workers are not exposed to the volume of repetitive movements and other work-related postures as in the case of brick paving.

19.4 Trade-Related Problems and Ergonomic Solutions

According to Hsiaso and Fosbroke (1997), an analysis of injury data indicates that 11 occupations are "at increased risk" as they represent 31% of the workforce, but account for 62% of the overexertion injuries. The occupations are general workers, carpenters, plumbers, drywall installers, roofers, electricians, structural metal workers, carpet layers, tile setters, plasterers, and machine operators. Among these occupational groups, there have been greater numbers of reported musculoskeletal disorders due to limited use of ergonomics within the work-site (Rwamamara, 2005a). In recent years, the industrialization of the construction industry has been conveyed as a way of improving ergonomics in the construction workplace. However, industrializing the industry has in fact also created numerous problems in making changes in the construction work environment (Rwamamara,

2005a). If changes are primarily motivated by the need to save money and the promise of increased productivity, workers may be resistant to changes, as higher productivity means more work with fewer workers (Schneider, 1999). Workers, along with other stakeholders in the production process, need to be included in the identification of high risk tasks and potential solutions. Then the industrialization of construction work could be said to be successful in terms of both building quality and financial gain for employers and clients, plus a safer and healthier work environment for the construction workers.

Research conducted among general contractors in South Africa investigated the impact of 23 traditional trades and activities on construction ergonomics (Smallwood, 1997). Table 19.3 indicates the impact of the trades and activities based upon an II with a minimum value of 0.0, and a maximum value of 3.0, ranked from greatest to least impact. The findings are notable in that although the IIs are <1.5 and the activities/trades can thus be deemed to have no or a minor impact as opposed to a major impact, the activities/trades do in fact all have an ergonomics effect, which indicates that the respondents do not have an understanding and appreciation of the impact of the activities/trades. In fact, activities or trades such as excavating, formwork, concreting, roofing, steel erecting, screeding, and bricklaying all require repetitive movements, use of body force, and

TABLE 19.3

Extent to Which Activities/Trades Impact on Construction Ergonomics according to Management

	Impact (%)						
Activity/Trade	**Don't know**	**No**	**Minor**	**Moderate**	**Major**	**II**	**Rank**
Excavating	3.7	18.5	27.2	33.3	17.3	1.46	1
Formwork	5.1	21.5	27.8	31.7	13.9	1.33	2
Concreting	4.9	21.0	29.6	30.9	13.6	1.32	3
Roofing	9.0	14.1	28.2	43.6	5.1	1.31	4
Plant operating	7.7	19.5	28.6	31.2	13.0	1.29	5
Steel erecting	15.6	20.7	23.4	24.7	15.6	1.15	6 =
Screeding	7.6	27.8	26.6	25.3	12.7	1.15	6 =
Bricklaying	6.3	26.7	27.8	32.9	6.3	1.13	8 =
Ceiling erecting	9.1	28.6	20.7	32.5	9.1	1.13	8 =
Block laying	10.0	27.5	22.5	33.7	6.3	1.09	10
Carpentry	7.7	28.6	27.3	29.9	6.5	1.07	11
Plastering	7.5	30.0	27.5	26.3	8.7	1.06	12 =
Reinforcing	12.8	21.8	34.6	20.5	10.3	1.06	12 =
Pipe laying	24.4	19.2	21.8	25.6	9.0	1.00	14
Paving	12.0	26.7	36.0	20.0	5.3	0.92	15
Painting	12.8	29.5	33.3	19.3	5.1	0.87	16
Waterproofing	17.1	23.7	38.2	15.8	5.3	0.86	17 =
Joinery	17.1	26.3	32.9	18.4	5.3	0.86	17 =
Ducting	28.6	24.6	27.3	11.7	7.8	0.74	19
Pipe fitting	32.1	20.5	32.1	11.5	3.8	0.67	20
Floor coverings	20.0	32.0	32.0	14.7	1.3	0.65	21
Glazing	25.0	27.6	34.2	11.8	1.4	0.62	22
Fencing	24.0	30.7	30.7	13.3	1.3	0.61	23

Source: Adapted from Smallwood, J.J., *Ergonomics SA*, 9(1), 6, 1997. With permission.

reaching away from the body. Furthermore, even though the highest levels of "don't know" responses are relative to subcontract activities/trades, the management of general contractors should be aware of the ergonomically related risks.

19.4.1 Solutions through the Influence of Clients and Designers

19.4.1.1 Clients

Clients influence construction risks both directly and indirectly. Directly in that they often select the type of structural frame, fabric, materials, and finishes. Indirectly through the selection of site; decision on project duration; prioritization of health and safety (HS); financial support of contractors' HS efforts; prequalification of contractors on health and safety HS; establishing project HS requirements; requiring of project HS plans; and conducting HS audits (Smallwood, 1998). The cost of accidents and the influence of ergonomics on project performance constitute an incentive to clients to contribute to contractor HS and ergonomics.

19.4.1.2 Designers

Designers influence ergonomics directly in that they produce the following aspects: the concept design, select the type of structural frame and fabric, undertake the detailed design, prepare details and specify materials; the type of structural frame affects the nature, scope, and logistics of the work, i.e., reinforced concrete versus structural steel; the type of structural frame, building fabric and finishes affect the nature of, and demand for means of ascending/descending, walkways and working platforms; the mass, volume, surface area, texture, edges, contents, and type affect the manner in which materials are handled; the characteristics of materials, along with configuration, affect the suitability of elements and components to be mechanically handled; the characteristics of materials affect materials storage requirements and housekeeping; plus the site coverage affects the availability of space for material storage, circulation paths, and roads (Smallwood, 2000a). Designers also influence ergonomics indirectly through choice of procurement system, effectiveness of design coordination, the use or nonuse of prequalification of contractors, selection of contractor, and project duration (Smallwood, 2000b). Certain procurement systems, such as design-build, engender ergonomics as a result of the integration of design and construction. Optimum design coordination of aspects such as services enhances ergonomics through optimum working space in ducts, and ceiling and roof spaces. Prequalification engenders the engagement of ergonomics conscious contractors. Project duration, if shortened to the extent that it results in a disproportionate amount of resources in the workplace, negatively affects ergonomics as a result of congestion. For many of these construction-site problems, ergonomic solutions have been proposed (Schneider and Susi, 1994), some of which can help reduce the risk factors present, and others which hold promise as interventions (Table 19.4).

19.5 Impact of Stages of Projects on Construction Ergonomics

Research conducted among general contractors in South Africa investigated the impact of the general 10 stages of projects on construction ergonomics (Smallwood, 2002). Respondents were required to respond relative to a five-point scale ranging from a minor

TABLE 19.4

Solutions to Work-Site Problems

Task	Solution
Heavy equipment operator	Better seat design
Vibration	Better handle design
Shoveling	Adjustable scaffolds
Laying masonry blocks	Keep brick stack at proper height
	Pump mortar to point of application
	Limit weight of blocks
	Redesign blocks with hand holds
	Better handle design
Carrying buckets of cement	Adjustable height saw horses
Formwork	Bent handle hammer design
	New forms that are easier to dismantle
	Use of smaller form components
	Enclosed cabs, better seat design
Crane operation	Tool for tying rods from standing height
Concrete floor work	Straight edge handle
	Welded fabric nets
	Vibration/noise dampened equipment
Chipping hammer vibration	Lighter weight models
	Attachment of sprayers to self for support
Spraying fireproofing	Use of hoist to crank ductwork to proper height
Installation of ductwork	Install on side wall rather than overhead in utility tunnels
Plumbing installation	Better design handles
Electrical work-screwdriving	Use of powered screwdrivers
	Use of TORX head screws
	Micropauses during continuous work
	Use of drill stand or bolt gun waist belt for overhead work
Drywall installation	Use of dollies, carts to transport boards
	Use of narrower boards (90 cm)
	Use of handles, proper training
	Use of swivel-head screw guns
	Plasterboard lifts
Elevator construction	Use of dollies, carts, lifting hooks, and better planning
	Use of cranes, dollies, smaller tubes of asphalt, better bucket handles
	Use of asphalt tanker rather than kettle
Building exterior	New tool for fastening roof from standing height
	Use of motorized scaffold, sheet clad storage device
Scaffold erection	Mechanical window installation device
	Use of hoists, newer scaffolds that are easier to carry and assemble
Painting	Flange on painters handle and neck pillow for overhead work
Installation of ceiling grid	Redesign of bucket handle and bucket

(*continued*)

TABLE 19.4 (continued)

Solutions to Work-Site Problems

Task	Solution
Floor glue spreading	Materials in smaller packages with handles
Carpet laying	Use of better hand tools, powered screwdrivers
	Use of standing spreader tool
Work at floor level	Use of power stretches instead of knee kicker
	Dollies for carpet rolls
Door installation	Use of wheeled stools with tool bins
	Combination knee pad/seat for kneeling work
Setting paving stones	Border drills
	Foot levers
Asphalt paving	Mechanical door installer
	Dolly for setting stones
	Better machines with less vibration

Source: Schneider, S. and Susi, P., *Am. Indust. Hygiene Assoc. J.*, 55(7), 635, 1994. With permission.

to a major impact. Eight of the ten stages were deemed to have more of a major than a minor impact: structural steel structures; reinforced concrete structures; roof; cladding/external fabric; installation of services (structure); ceilings; walling/partitions; and external works. Finishes, site clearance, and earthworks were deemed to have a minor impact. A comparative study conducted in India and South Africa investigated a range of ergonomics issues (Smallwood and Haupt, 2007). Table 19.5 indicates the extent to which the various stages of projects impact on construction ergonomics in terms of a mean score ranging between 1.0 and 5.0 based upon percentage responses to a scale of 1 (minor) to 5 (major). It is notable that the average of all the mean scores is above the midpoint score of 3.0, which indicates that the stages can be deemed to generally have more of a major than a minor impact on construction ergonomics. However, in terms of ranges, given that the means of the mean scores for those stages ranked first to ninth are $>3.4 \leq 4.2$, they can be deemed to have between a major/near major impact on construction ergonomics. The average of the mean scores relative to walling/partitions indicates that it can be deemed to have less impact on construction ergonomics.

The relevance of these findings is that all project stakeholders need to focus on the stages which have the greater impact on construction ergonomics. Focus includes hazard identification and risk assessment, and if possible amendment of the design, and/or details, and/or specification, and adoption of alternative methods of work and organization of the work place.

The extreme right-hand column in Table 19.5 (as in Tables 19.6 and 19.8) presents the percentage difference (the ratio of the higher to the lower mean score, as registered on a scale of 1.0–5.0). It is noteworthy that in all stages listed in Tables 19.5, 19.6, and 19.8, the higher recorded mean score is relative to South Africa. The stages with percentage differences:

- 20% are installation of services (structure) (32.4%); ceilings (23.8%); cladding/external fabric (23.3%); and walling/partitions (20.5%).
- 10% ≤ 15% are finishes (13.2%); structural steel structure (11.3%); and reinforced concrete structure (10.8%).

TABLE 19.5

Extent of Impact of the Various Stages of a Project on Construction Ergonomics

Stage	India		South Africa		Mean		Difference (%)
	MS	Rank	MS	Rank	MS	Rank	
Structural steel structure	3.82	1	4.25	1	4.03	1	11.3
Reinforced concrete structure	3.78	2	4.19	3	3.98	2	10.8
Roof	3.69	3	3.97	5 =	3.83	3	7.6
Installation of services (structure)	3.18	9	4.21	2	3.70	4	32.4
External works	3.53	4	3.85	7	3.69	5	9.1
Ceilings	3.28	6	4.06	4	3.67	6	23.8
Cladding/external fabric	3.22	8	3.97	5 =	3.59	7	23.3
Site clearance and earthworks	3.45	5	3.61	9	3.53	8	4.6
Finishes	3.26	7	3.69	8	3.48	9	13.2
Walling/partitions	2.89	10	3.55	10	3.22	10	22.8

Source: Smallwood, J.J. and Haupt, T.C., *Ergonomics SA*, 19(1), 30, 2007. With permission.

19.6 Effect of Design, Procurement, and Construction Aspects on Ergonomics

The comparative study conducted in India and South Africa also investigated the extent to which various design, procurement, and construction aspects affect construction ergonomics (Smallwood and Haupt, 2007). Table 19.6 indicates the extent to which they do in terms of mean scores ranging between 1.0 and 5.0, based upon percentage responses to a scale of 1 (minor) to 5 (major). It is notable that the means of the mean scores of all

TABLE 19.6

Extent to Which Aspects Negatively Affect Construction Ergonomics

Aspect	India		South Africa		Mean		Difference (%)
	MS	Rank	MS	Rank	MS	Rank	
Degree of contractor awareness relative to ergonomics	3.89	1	4.26	2	4.07	1	9.5
Standard of site house keeping	3.40	4	4.31	1	3.86	2	26.8
Degree of contractor planning	3.50	2	4.13	3	3.81	3	18.0
Amount of work relative to project duration	3.41	3	3.91	6	3.66	4	14.7
Degree of mechanization	3.19	8	4.03	4	3.61	5	26.3
Format of materials	3.21	6 =	3.94	5	3.57	6	22.7
Specification	3.21	6 =	3.61	8	3.41	7	12.5
Details	2.98	9	3.65	7	3.31	9	22.5
Type of procurement system	3.27	5	3.25	10	3.26	7	0.6
General design	2.86	10	3.56	9	3.21	10	24.5

Source: Smallwood, J.J. and Haupt, T.C., *Ergonomics SA*, 19(1), 30, 2007. With permission.

the aspects are above the midpoint score of 3.0, which indicates that the aspects can be deemed to generally have more of a major than a minor impact on construction ergonomics. However, in terms of ranges, given that the means of the mean scores for those stages ranked first to seventh are >3.4 ≤ 4.2, they can be deemed to have between a major/near major impact on construction ergonomics. The degree of contractor awareness relative to construction ergonomics, standard of site housekeeping, degree of contractor planning, and degree of mechanization are construction-related aspects. However, the degree of mechanization is influenced by design, and the amount of work relative to project duration is procurement related, and is influenced by clients and principal agents. Format of materials is manufacture related, and specification design related. The means of the remaining three aspects are >2.6 ≤ 3.4, and therefore the aspects can be deemed to have between a near minor impact to impact/impact on construction ergonomics—details, procurement system, and general design.

In Table 19.6, it is noteworthy that in every case the higher mean score is relative to South Africa. The aspects with percentage differences: >20% are standard of site housekeeping (26.8%); degree of mechanization (26.3%); general design (24.5%); format of materials (22.7%); and details (22.5%); >15% ≤ 20% are degree of contractor planning (18%), and > 10% ≤ 15% are amount of work relative to project duration (14.7%) and specification (12.5%).

19.7 Aspects Which Require Attention

Previous research conducted in South Africa investigated the extent to which various aspects of construction had an impact on ergonomics (Smallwood, 1997). Table 19.7 presents the findings according to management and workers, ranked in terms of most to least attention, based upon the mean percentage of affirmative response. Although the aspects are all construction related, designers essentially influence most aspects. Designers influence materials directly in that they evolve the design concept, select the type of frame and

TABLE 19.7

Construction Ergonomic Related Aspects Which Require Attention According to Management and Workers

	Management		Workers		Mean	
Aspect	**Yes (%)**	**Rank**	**Yes (%)**	**Rank**	**Yes (%)**	**Rank**
Materials handling	78.8	3=	76.3	1	77.6	1
Working platforms	81.7	2	70.5	3	76.1	2
Housekeeping	78.8	3=	70.8	2	74.8	3
Means of ascending/ descending	83.8	1	65.6	5=	74.7	4
Materials storage	74.1	5	69.7	4	71.9	5
Walkways	71.8	6	65.6	5=	68.7	6
Mechanization	64.9	7	50.4	7	57.7	7
Circulation paths	53.2	8	41.3	8	47.3	8
Circulation roads	51.3	9	37.2	9	44.3	9

Source: Adapted from Smallwood, J.J., *Ergonomics SA*, 9(1), 6, 1997. With permission.

fabric, undertake the design, prepare details, and specify materials. Designers influence materials handling and mechanization directly through the conceptual design, choice of structure, design in general, details, and specification of materials. The mass, volume, surface area, texture, edges, contents, and type affect the suitability of elements and components to be mechanically handled. The characteristics of materials affect materials storage requirements and housekeeping. Site coverage affects the availability of space for materials' storage, circulation paths, and roads. The type of building fabric and finishes affects the nature of, and demand for means of ascending/descending, walkways, and working platforms.

19.8 Multi-Stakeholder Interventions

The ergonomic and general HS benefits of multi-stakeholder solutions and interventions have been advocated before in a systematic method for identifying hazards and operability problems in a facility (Lingard and Rowlinson, 2005). Furthermore, a participatory design involving all stakeholders was suggested to establish a healthy and safe construction workplace over and above the enhanced productivity and quality (Rwamamara and Holzmann, 2007). The comparative study, conducted in India and South Africa, also investigated the extent to which various design and construction aspects could contribute to an improvement in construction ergonomics (Smallwood and Haupt, 2007). Table 19.8 indicates the extent to which aspects could contribute to an improvement in construction ergonomics in terms of mean scores ranging between 1.0 and 5.0, based upon percentage responses on a scale of 1 (minor) to 5 (major). It is noteworthy that the means of all the mean scores

TABLE 19.8

Extent to Which Aspects Could Contribute to an Improvement in Construction Ergonomics

	India		South Africa		Mean		Difference
Aspect	**MS**	**Rank**	**MS**	**Rank**	**MS**	**Rank**	**(%)**
Awareness	4.63	1	4.52	4	4.57	1	2.4
Safe working procedures	4.35	2	4.55	1 =	4.45	2	4.6
Contractor planning	3.99	3	4.55	1 =	4.27	3	14.0
Workshops on site	3.85	6	4.42	6	4.14	4 =	14.8
Mechanization	3.82	7	4.45	5	4.14	4 =	16.5
Constructability (general)	3.73	8	4.53	3	4.13	6	21.4
Design of equipment (construction)	3.86	5	4.30	8	4.08	7	11.4
Reengineering	3.90	4	4.19	11	4.05	8	7.4
Prefabrication	3.66	10	4.31	7	3.99	9	17.8
Design of tools	3.61	11	4.27	9	3.94	10	18.3
Specification	3.68	9	4.09	12	3.89	11	11.1
Details	3.61	12	4.03	13	3.82	12	11.6
General design	3.21	13	4.22	10	3.71	13	31.5

Source: Smallwood, J.J. and Haupt, T.C., *Ergonomics SA*, 19(1), 30, 2007. With permission.

are above the midpoint score of 3.0, which indicates that the aspects can be deemed to generally have the potential to contribute to a major, rather than a minor improvement in construction ergonomics. Furthermore, it is significant that the means of three of the 12 aspects are >4.2 ≤ 5.0, which indicates that the aspects can be deemed to have between near major and major potential to contribute to an improvement in construction ergonomics. Although awareness is generic, safe working procedures and contractor planning are contractor-related aspects.

The means of the remaining aspects are >3.4 ≤ 4.2, and therefore they can be deemed to have near major potential to contribute to an improvement in construction ergonomics. Although workshops on site and mechanization are contractor-related aspects, the degree of mechanization is influenced by design. Constructability (general) prefabrication, specification, details, and general design are design-related aspects. However, they are influenced by clients, project managers, and quantity surveyors. Design of equipment (construction) and design of tools in turn are manufacturer related. Reengineering is a design/procurement/construction-related aspect that is influenced by all project stakeholders, i.e., clients, project managers, quantity surveyors, general contractors, cocontractors, suppliers, and manufacturers. The extreme right-hand column calculated as discussed above again shows higher scores from South African respondents compared with the Indian respondents. The aspects with percentage differences:

- 20% are general design (31.5%) and constructability (21.4%)
- 15% ≤ 20% are design of tools (18.3%); prefabrication (17.8%); and mechanization (16.5%)
- 10% ≤ 15% are workshops on site (14.8%); contractor planning (14%); details (11.6%); design of equipment (construction) (11.4%); and specification (11.1%)

The nature and scope of a "Where does it hurt?" research project conducted among workers in South Africa presented the opportunity to investigate the relationship between the work-site problems encountered and the ergonomics-related aspects which require attention (Smallwood et al., 2000a). These research projects identified the relationships which were either statistically significant in terms of association or dependence, or both. It is notable that nine of the 13 (69.2%) relationships presented involve requiring attention to mechanization. It is significant that seven of the nine (77.8%) were statistically significant in terms of both ordinal scale scores and observed frequencies. It is also notable that in terms of aspects requiring attention, three (23.1%) of the 13 relationships presented involved materials handling, and in terms of problems, four (30.8%) of the 13 relationships involved handling heavy equipment or heavy materials.

In a U.S. case study identifying multi-stakeholder ergonomics interventions used to reduce musculoskeletal loading for building installation tasks (Albers et al., 2005), it was found that engineering interventions described in stakeholder meetings included tools, equipment, and engineered building materials; administrative controls largely consisted of training and education programs; and modifications of work and management practice. However, most participants believed that there were significant limits to the impact individual contractors and trades people could have in facilitating ergonomics improvements in the building and construction industry. Furthermore, in a study on the impact of the industrialized construction process on the health of construction workers and ergonomics in the construction workplace, it was found that the production process had a positive impact in improving the construction work environment in terms of reduction of risk factors conducive

to musculoskeletal disorders; nonetheless the quasi-nonexistent worker consultation on health measures made the industrialization less optimal (Rwamamara, 2005b).

19.9 Summary

A range of ergonomically related problems are encountered in IACs as well as IDCs in relation to construction. Furthermore, all trades and activities contribute to the existence of such problems. Many of these problems have their origin in the nature of work processes which are far more suboptimal in IDCs as they are exacerbated by using a manual approach when a mechanical approach would be more appropriate. Mechanization thus constitutes a potential holistic intervention, which is complemented and facilitated by prefabrication and preassembly. However, this will require a paradigm shift in developing countries, which invariably view construction as a creator of employment in terms of labor intensive construction. Although such a perspective may be noble in terms of intentions, it is not sustainable and results in the marginalization of people's health and well-being through the onset of musculoskeletal disorders.

Research indicates that ergonomics factors are impacted upon by design, procurement, and construction, and thus solutions require a multi-stakeholder approach incorporating clients, project managers, designers, quantity surveyors, contractors, and material manufacturers and suppliers. Invariably a catalyst is required to realize change. Awareness constitutes the catalyst, which in turn entails a prerequisite in the form of education and training. Therefore, the onus resides with educators and trainers involved in construction work, and all tertiary level environment and skills training programs should address construction ergonomics.

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20

Keeping the Wheels Turning—Practical Application of Ergonomics in the Automotive Industry

Jonathan P. James and Genevieve James

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20.1 Introduction

The global automotive industry is a significant contributor to manufacturing and capital expenditure with product development costs running into billions of dollars per annum. Manufacturing plants are spread around the world, and vary in levels of sophistication from "state-of-the-art" automation and robotics in developed regions such as Japan and the United States, to work processes based on simple manual tasks in many developing regions, for example, South Africa.

Despite growing mechanization and automation, manual work is still a common practice in industrial settings, particularly in developing areas (Kumar, 1995; Dempsey, 1998; Scott et al., 2003). Dempsey (2003) stated that manual materials handling (MMH) continues to represent a major source of loss in the workplace, resulting in a need for applied research and practice to address the design and evaluation of MMH exposures. The automotive manufacturing process requires the completion of a number of specific manual tasks. Working

in an industrially developing countries (IDC) setting James and Todd (2003) observed that operators frequently adopt suboptimal working postures during the completion of tasks along the automotive assembly line. Lifting, carrying, and lowering of vehicle panels are probably the most commonly used manual activities, with substantial variations at different stages along the production line. For example, engine assembly lines require the operator to lift, carry, and place heavy engine components, including crankshafts which are an awkward shape to carry and exceed 30 kg in mass, without mechanical assistance. Automotive paint shop areas require frequent skid or trolley pushing and pulling, which taxes the operators working in this particular area of the manufacturing process. The trim and assembly lines also place a significant amount of stress on the worker as many of the tasks are repetitive in nature and require awkward postures to be adopted.

Essentially, the automotive sector in developing regions is still largely characterized by a prevalence of manual labor, where suboptimal working conditions are commonplace. In addition, these automotive manufacturers are constantly striving for higher production in order to remain competitive with global manufacturers. This results in decreasing work-cycle times, increasing pressure being placed on the manual motor assemblers to meet the demands, and a growing need for ergonomics interventions to improve working conditions and assist with reducing wasted time and effort, and the physical stresses placed on the workers. This chapter focuses on the lessons learnt during practical application of workplace interventions based on sound ergonomics principles in various automotive manufacturing plants in South Africa.

20.2 Case Studies—Low-Cost Ergonomics in the Automotive Sector

The automotive industry has long been proactive in the discipline of ergonomics, with many examples of workplace improvements and redesign reported in both industrially developed and developing countries. However, many of the advances in robotics, automated technology and workplace improvements have not been widely implemented in developing countries, the consequence being an urgent need for basic workplace changes. The following IDC-specific case studies provide examples of low-cost changes effected in the automotive workplace, which have been shown to make a significant contribution to good ergonomics practice. The first case study relates to Industry A and will be used to consider an empirical study conducted both in the field and in a well-equipped laboratory (James, 2007), while the remainder of the case studies cover practical application of ergonomics within an automotive plant (Industry B). Case study 1 covers the integration of field findings with rigorous laboratory experimentation which considered the effects of a workplace redesign of identified problems areas and assessed the efficacy of the proposed interventions to pushing and pulling tasks (James, 2007). The additional case studies focus on *in situ* interventions, where problems have been solved with ongoing interaction with the workers in the automotive plant who are consulted as part of an ongoing participatory approach to practical ergonomics in Industry B.

20.2.1 Case Study 1—Industry A

The transfer of "work-in-progress" vehicle units in many IDC industries is still completed manually, and this poses significant risks to the workers. For several years, Industry A

has proactively sought alternative methods for task completion and has prioritized workplace redesign in cases where the task demands are shown to be excessive. An example of this is in the redesign of the transfer units used in the Paint-shop which prioritized the reduction of the physical load requirements placed on the musculoskeletal system of the workers, and also aimed to reduce the distance covered by them in this area in order to improve work efficiency on the transfer line and to minimize the pushing and pulling of vehicle units and skids. Manual vehicle transfer via pushing and pulling efforts not only places the worker in an awkward working position, but also substantially increases the risks of accidents and slipping and falling on the line. *In situ* observations highlighted the need to minimize the suboptimal push–pull efforts and to verify the potential benefits of workstation redesign based on rigorous laboratory results.

20.2.1.1 Task Design and Problem Addressed

Vehicle transfer in an automotive Paint-shop is required to move the welded vehicle unit from the start of the paint-line into the painting bay, and then subsequently out of the painting bay into the drying furnace, and finally the unit is transferred into the trim and assembly area. These transfers are completed manually in Industry A. Consequently, the workers are required to push and pull the vehicle transfer trolley at frequent intervals during the work-shift (see Figure 20.1). Approximately, 70 vehicle units are transferred per worker and the time spent pushing or pulling the transfer trolleys ranges from approximately 3–7 s per push–pull effort. The frequent pushing and pulling activities necessitated an intervention strategy that allowed for simplified vehicle transfer and minimized the push–pull force requirements of the worker.

Laboratory experimentation (James, 2007) showed that the task design for the vehicle transfer greatly increased loading of the shoulder joint complex and placed significant

FIGURE 20.1
Vehicle transfer preintervention in the Industry A Paint-shop.

stress on the musculoskeletal system. Electromyographic (EMG) responses were collected in a simulated session in the laboratory (based on the observations preintervention in Industry A) and used to evaluate the maximal left and right "medial deltoid" activity recorded during the one- and two-handed pushing task. The averaged EMG data (James, 2007) showed that the left and right medial deltoids were excessively taxed during preintervention transfer trolley pushing, which, coupled with unsafe working postures, led to a considerably high level of risk to the operator. Postintervention pushing using both hands at the front of the unit demonstrated the impact of balanced loading of the medial deltoids with an averaged EMG activity of 55.3 and 58.4 μV in left and right shoulders, respectively. Significant differences were observed for both the averaged and peak activity between the original two-handed push and the proposed intervention (reduced from 148.1 to 55.3 μV for two-handed trials).

Based on the laboratory findings and recommended interventions, Industry A sought to redesign the workstation and provide an alternative transfer system which could minimize the risk to the worker. Laboratory experimentation demonstrated that the one-handed pushing task differentially taxed the upper-extremities and required changes to be made. Key research findings demonstrated that the introduction of an even pushing action distributed the load between the left- and right-hand sides, thereby reducing the stresses placed on the rotator cuff of the dominant limb, and the twisting of the spine; based on theoretical three-dimensional (3D) static strength prediction program (SSPP) modeling, the percentage of the population capable of completing the pushing task was improved from 17% to 99%. The 3D low back compression model showed a significant reduction from 1835 to 421 N postintervention indicating a low level of compressive forces well below the acceptable working limit once the pushing action was symmetrical.

Previous research carried out by James and Todd (2003) assessed the impact of pushing and pulling tasks on operators working in an IDC automotive industry. This study revealed that there were substantial differences in the maintenance of the roller systems on which the vehicles were being moved, and where this was particularly negligent it resulted in a substantial increase in the resistance of the support base and subsequent force output required. Furthermore the operator was required to push and pull the vehicles over uneven surfaces, increasing the likelihood of tripping. Haslam et al. (2002) found that slipping is more likely when pushing or pulling than with unencumbered gait owing to higher shear forces between feet and floor. Workplace changes in the form of a ride-on transfer trolley and changes to the processes required of each work in Industry A have thus resulted in a substantial reduction in risk factors in this area of the plant. In contrast to the preintervention observations where the work demands were excessive, and working postures were poor and potentially hazardous, the postintervention observation clearly demonstrated the benefits of effective ergonomics intervention in the workplace (James, 2007). Through automation of the transfer trolley, the task has been simplified, but the operator retained as shown in Figure 20.2.

20.2.1.2 Summary—Practical Application of Ergonomics Principles

The ride-on transfer unit allowed workers to carry out the transfer without having to adopt awkward working postures, and eliminated pushing and pulling of the unit along the transfer tracks; an improvement immediately experienced by the workers. Significant reductions were observed for all pushing and pulling subtasks postintervention (James, 2007). Pre- versus postintervention ratings of perceived exertion (RPE) are shown in Table 20.1. In addition to changes in RPE, reductions were also observed in heart rate and

FIGURE 20.2
Vehicle transfer postintervention in the Industry A Paint-shop.

TABLE 20.1

Changes in RPE Pre- versus Postintervention in the Paint-Shop Area of Industry A

	Central RPE				Local RPE (Arms and Back)			
	Min 30	**Min 60**	**Min 90**	**Min 120**	**Min 30**	**Min 60**	**Min 90**	**Min 120**
Preintervention	11.0	11.6	11.0	11.0	12.2	13.0	12.3	13.0
	(1.22)	(1.14)	(1.10)	(1.26)	(3.27)	(2.45)	(2.45)	(1.67)
Postintervention	7.3*	8.0*	8.7*	8.8*	7.7*	7.7*	8.0*	8.3*
	(0.56)	(1.00)	(0.58)	(0.58)	(0.58)	(0.58)	(1.00)	(0.58)

Source: James, J.P., Field and laboratory analyses of manual tasks in the South African automotive industry. Rhodes University, Unpublished PhD dissertation, 2007.

Note: Means with standard deviations in brackets, shaded area postintervention;

* denotes significant difference ($p \leq 0.05$) between pre- and postintervention responses.

body discomfort reported postintervention. Heart rates ranged from 80 to 115 bt · min^{-1} in the Paint-shop preintervention, and between 75 and 90 bt · min^{-1} postintervention. Ratings of body discomfort by Paint-shop workers confirmed a notable reduction in operator perception of intensity of discomfort from 5.5 (±1.93) on the 10-point rating scale of the body discomfort scale (BDS) during the first hour which was reduced to 3.3 (±0.76) postintervention, and in the second hour from 5.8 (±1.71) to 3.4 (±0.79). In contrast to the preintervention observations on the plant floor where the Paint-shop work demands were excessive and working postures were poor and potentially hazardous, the postintervention observation clearly demonstrated the benefits of effective ergonomics intervention in the workplace by eliminating awkward postures and improving conditions in the Industry A Paint-shop.

20.2.2 Case Study 2—Industry B

20.2.2.1 Task Design and Problem Addressed

Where in a more developed country many of the automotive manufacturing processes may be performed by robots, the manual nature of the work in South Africa provides an important source of employment in a country where unemployment is a major area of concern. Although this manual work provides employment in IDCs, MMH has been shown to be highly prevalent and instrumental in creating a number of complex problems for workers in both IDCs and IACs (Dempsey, 1999; Scott and Christie, 2004). Past research in this area has focused largely upon the load, the task frequency, and the work-shift duration. In addition, vertical and horizontal movement patterns of the workers have been widely considered during the evaluation of the physical stressors experienced with manual tasks (Marras et al., 1993; Davis and Marras, 2003; Dempsey, 2003). With production demands continuously being raised, the risk of developing chronic musculoskeletal problems has increased. Industry B recognized the need for ergonomics input to ensure that employees can meet these increasing production demands without over taxing their physical capacity and exposing them to risk factors leading to injuries, yet still maintaining a high level of quality. The increasing production demands mean that more units are produced and tact-time is reduced, so that more units are produced in a shorter time period by the same number of people. (Tact-time refers to the time needed to manufacture one unit of a product, and it is measured as the elapsed time between the completion of one unit and the completion of the next.) For the purposes of this case, study workplace changes have been categorized into examples of good ergonomics practice in Industry B. Examples encompass changes which have been affected through workplace redesign, work reorganization, and changes to working postures. Worker responses to changes have been recorded and will be used to evaluate the long-term benefits of the redesign of each of the tasks. Measures that will be used over the longer term include RPE, BDS, and the job satisfaction index.

20.2.3 Workstation Redesign—Improving the Bumper Inspection Task

20.2.3.1 Task Design and Problem Addressed

During bumper inspection, the person carrying out the task is required to inspect the paint quality and then fit reflective lights with the aid of a pneumatic hand-tool. Previously, the employee would first place the bumper on the jig and carry out both tasks at a fixed waist height. This fixed height forced the employee to adopt an unnatural stooped posture while carrying out the inspection.

The revised bumper inspection workstation is an example of a height-adjustable working platform, which has been specifically designed to reduce the task demands of the inspection task. With the introduction of this height-adjustable jig, the employee removes the bumper from a trolley and places it on the jig while it is in the lowered position. A foot pedal is then operated to raise the jig so that the bumper is positioned at eye level. This enables the employee to carry out the inspection without having to adopt an awkward stooped posture (see Figure 20.3a). The employee is then required to fit reflective lights (Figure 20.3b), which is done after the foot-pedal is used to lower the jig. This enables the employee to operate the hand-tool and perform the task at waist height without having to elevate or flex the shoulder joint in order to do so.

(a) (b)

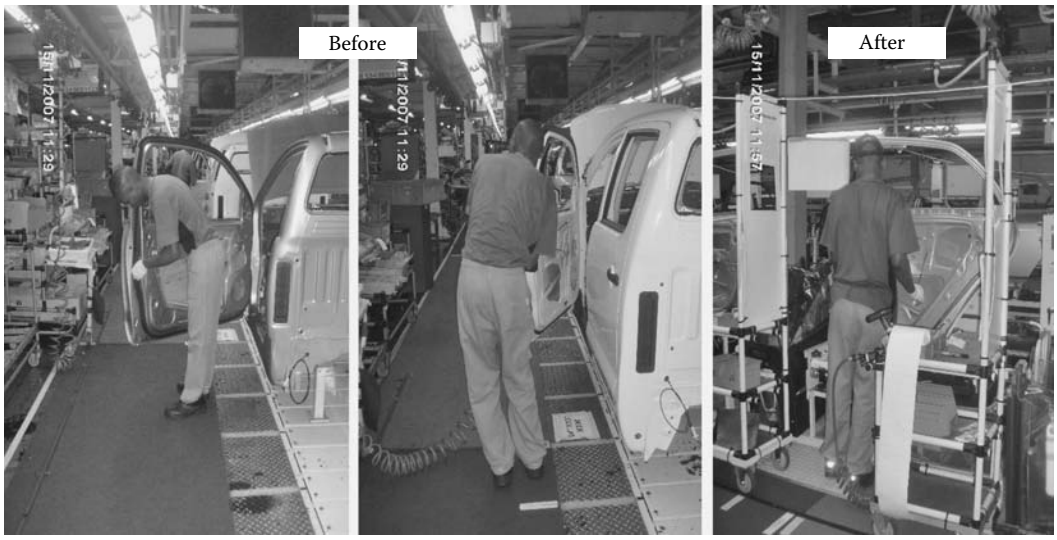
FIGURE 20.3
Adjustable bumper workstation. (a) Raised working platform for inspection task and (b) lowered platform for fitment of parts.

20.2.4 Reorganization of Working Cycle—Interior Door Assembly

20.2.4.1 Task Design and Problem Addressed

There are several parts which are required to be fitted to the interior of vehicle doors. Examples of these include window winders, door handles, and sealing rubbers. The interiors of all vehicle doors were previously assembled once the door was already fixed to the vehicle, thus resulting in awkward postures including excessive hip and spinal flexion (Figure 20.4a), as well as some lateral bending and axial rotation (Figure 20.4b). These postures resulted in additional forces being placed on the spine, thereby increasing the risk of developing work-related spinal injuries.

A new production line has recently been developed with the identified risk factors being taken into consideration. The line was reorganized so that the door interiors are assembled prior to the door being fitted to the vehicle. Assembling the door interiors away from the vehicle body means that the position of the activity of assembling the interior is not constrained by the position of the vehicle body. This has allowed for an improved workstation design which enables the employees to assemble the door interiors in a natural upright posture with reduced risk of developing a musculoskeletal disorder. Once the entire interior door assembly is complete, the door is fitted to the vehicle. Figure 20.4c demonstrates the improved working posture adopted while performing this task. In summary, the reorganization of the line, so that the door is fitted to the vehicle only after having been completely assembled, prevents the employee from being forced into spinal and hip flexion, with taxing axial rotation and lateral bending.

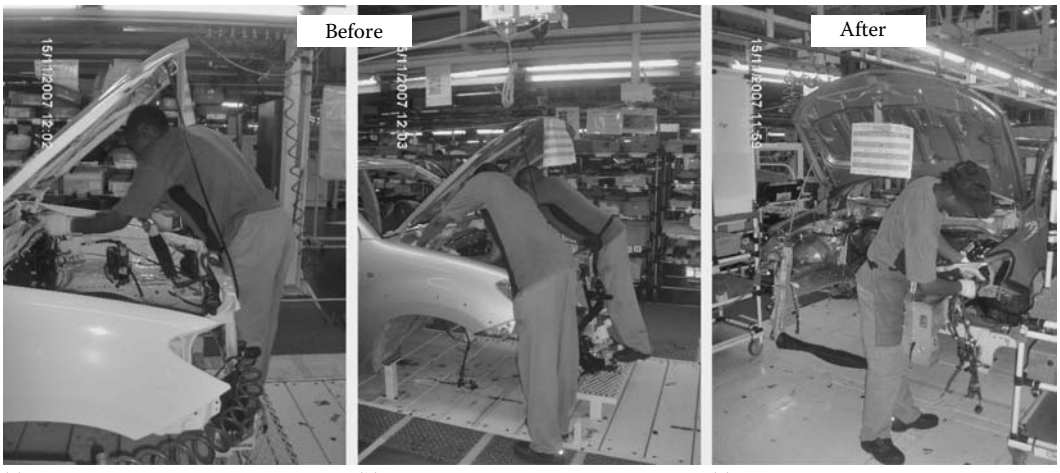


(a) (b) (c)

FIGURE 20.4
Interior door assembly once door is fitted to vehicle (a, b) and before being fitted to vehicle (c).

20.2.5 Minimizing Poor Working Postures—Fitment of Cables in Engine Compartment

The vehicles in Industry B were previously assembled in such a way that the employees fitting cables for lights, windscreen wipers, and other cables in the engine compartment had a horizontal reach well beyond their base of support in order to access the points at which cables are required to be fitted. As it is evident in Figure 20.5a and b, the fully assembled vehicle body prevents employees from being able to obtain closer access to the fitment points of the vehicle.



(a) (b) (c)

FIGURE 20.5
Engine compartment cable fitment on the old line (a, b) and the new line (c).

Figure 20.5c demonstrates the reorganized assembly of the vehicle on the new line. The fitment of cables in the engine compartment takes place before the anterior external body of the vehicle is assembled. This allows the employee to gain closer access to the fitment points and the horizontal reach factor is reduced significantly. This reduces the shearing and compression forces imposed on the spine and thereby reduces physical discomfort, as well as the risk of developing a musculoskeletal disorder particularly in the lower back region.

Basic workplace changes in the form of simple redesign, reorganization, and effective task ordering have resulted in a significant improvement in working conditions in Industry B. The minimizing of unacceptable working postures has further added to the impact of workplace changes in Industry B, with higher levels of worker job satisfaction reported at the redesigned workstations.

20.3 Analysis of Cost–Benefit to the Automotive Industry

Cost–benefit analysis provides a useful tool to quantify the impact of changes and effective return on investment to the organization. The two following tables are based on theoretical extrapolations based on the current work demands (before) and detail the potential benefits of workplace redesign (after) in each of the respective workplaces. Considering case study 1 (Industry A) as an example, the redesign of the transfer processes reduced the physical demands of the task through reductions in the push–pull efforts required of the worker. Figure 20.6 shows the intervention benefits for the worker in the application

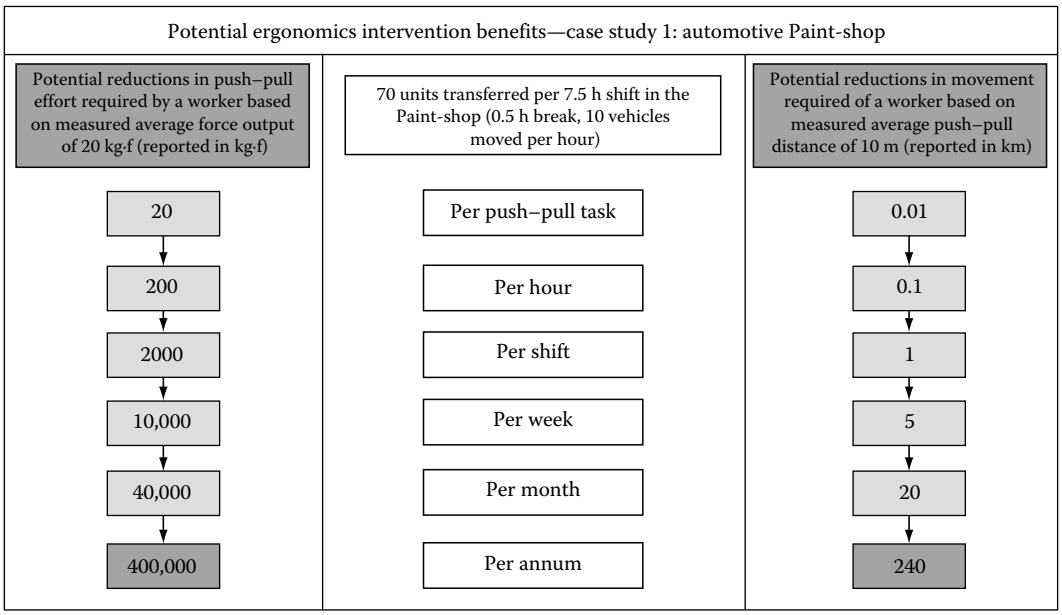


FIGURE 20.6
Case study 1 (Industry A) Paint-shop "cost–benefit" analysis.

of the automated transfer trolley. The intervention of the automated trolley resulted in a reduction in push–pull distance of 240 km per annum which ultimately would lead to push–pull force reductions of 400,000 kg·f per annum per worker in the Paint-shop. The subsequent use of the trolley has resulted in a reduction in workplace injuries and reduction in absenteeism in Industry A, thereby saving the company medical costs plus the cost of hiring and new employee training. Although the original capital outlay for the transfer trolley was in excess of US$10,000 per unit, this cost has been easily recouped through the improvements evidenced in work efficiency and decreases in work-cycle time.

Similarly, in Industry B, the interventions proposed have had a significant impact on the reduction in workplace stressors imposed on the employees working in each of the three areas assessed. For example, the interior door assembly (shown in Figure 20.4) required the worker to frequently work in suboptimal postures. The modifications to the door jig have resulted in an elimination of the need for the worker to laterally bend and axial rotate when completing the interior door assembly tasks. Figure 20.7 shows the potential intervention benefits for the worker completing the interior door assembly in Industry B. A change to the symmetry of the door jig resulted in a significant reductions in unnecessary movements, which place significant stressors on the workers' musculoskeletal system. Preintervention workers were axially rotating and laterally bending 2240 times per shift. In addition, they were spinally flexing 2800 times per shift due to the awkwardness of the door assembly task. A simple redesign of the jig has resulted in elimination of the axial rotation and lateral bend requirements for this job. Over a year, this will result in the elimination of 2,668,000 efforts of axial rotation and lateral bending. Spinal flexion has also been substantially reduced by 60% from 3,360,000 to 1,344,000 efforts per annum. The key benefit of the interior door assembly redesign is thus the reduction in the stresses being continuously placed on the musculoskeletal system generally and the spine specifically.

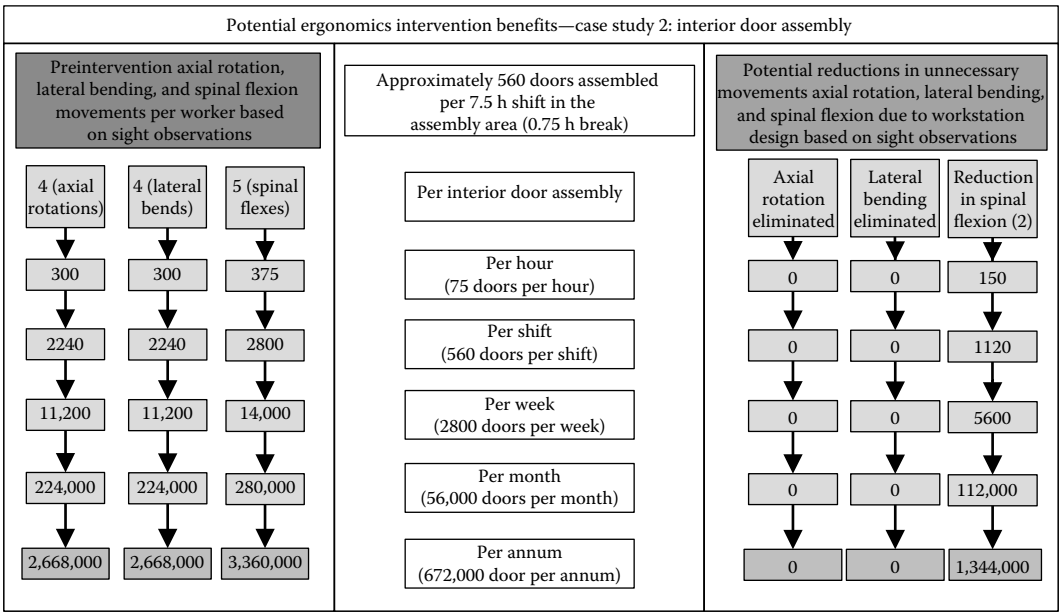


FIGURE 20.7
Case study 2 (Industry B) Interior door assembly line "cost–benefit" analysis.

The outcome of this small change should be reflected in decreased workplace injury and absenteeism which will be a major cost saving to Industry B in the future. The practical application of ergonomics in these two South African automotives industries has thus already demonstrated real benefits to the workforce at a minimal cost when evaluated against the capital expansion costs of the two industries under investigation.

20.4 Summary

The application of ergonomics in IDCs such as South Africa is dependent on well-thought-out and directed research being conducted *in situ* on manual laborers who are daily required to move extreme loads while adopting awkward working postures under suboptimal working conditions. Having evidenced various work settings and varied working conditions, the following recommendations are made in an attempt to highlight the steps required to facilitate the practical application of ergonomics within the IDC automotive environment:

- Automotive research needs to be conducted *in situ* on a variety of manual laborers in IDCs within their actual working environments. Assessments need to encompass a holistic evaluation of biophysical, physiological, and perceptual measures for automotive industrial workers.
- The global automotive industry, given the resources available, needs to be far more proactive in the application of ergonomics planning and interventions in the workplace, particularly in developing regions. Manufacturing plants need to be tasked with the establishment of ergonomics working groups or "facilitation teams" (Scott et al., 2003), who must provide detailed input during preparation and implementation of any workplace improvements or changes.
- Trained ergonomists are part of the multidisciplinary teams of all multinational automotive organizations, and the same appointments need to be made in advancing IDC industries.
- The utility of a macro–micro ergonomics approach (Scott et al., 2003) is thus proposed for the automotive industry, which has great potential to be the forerunner in the utilization of "applied" ergonomics in IDCs. The specific changes implemented during these two case studies could be used as examples for other work areas where manual labor still predominates.
- Automotive plants need to more precisely document "best practices," and to quantify the cost–benefit accounting of ergonomics interventions applied in the workplace.

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Part V

Regional Experiences: How Needs Are Being Addressed Universally

21

Assessing Available Resources to Meet Ergonomics Needs in the Subregions of West and Central Africa

Samson Adaramola

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21.1 Introduction

Any publication on ergonomics in industrially developing countries (IDCs) highlights the need to address the ergonomic challenges in West and Central African subregions. Even though differences in priorities exist in these subregions, there are some similarities, and exchange of information and international collaboration can greatly support the solving of existing problems faced daily in most working situations. Through such dialogue, one can begin to recognize which strategies need to be sustained and from whose perspective best practices should be considered. This will then assist with the formulation of practical outputs for working toward sustainability. Key role players involved in interventions aimed at improving the working environment of these developing countries must have a real understanding of the particular country's needs as well as identifying a suitable entry point for takeoff. Strategies which can be used to implement ergonomics programs are knowledge, advocacy, capacity building interventions, and the know-how to effectively use what is already there is essential.

The West African and Central African zones are two major diverse regions of the African continent. The Central African region is considered to include Burundi, Central African Republic, Chad, Democratic Republic of Congo, and Rwanda. While the West

African subregion comprises of Benin, Burkina Faso, Cameroon, Cape Verde, Congo, Cote d'Ivoire, Gabon, Gambia, Guinea-Bissau, Equatorial Guinea, Ghana, Liberia, Mali, Mauritania, Niger, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, and Togo and has an estimated population of 350 million people (ILO, 2007). These countries of West and Central Africa are regarded as IDCs, going through political, social, and economic transition. At the same time, they have to address huge problems of poverty and hazardous work conditions.

21.2 Changing Work Life

During the past decades, working life in these regions has undergone great changes. Not only the work itself, but also our opinion of work has changed. We now know that a good working environment should not only be healthy and safe, but should also encourage personal and professional development, job satisfaction, and personal fulfillment; all of which contribute to improved work quality and productivity. We know that the way work is organized is of importance and that situations in the labor market will affect the work, workers, and their health and well-being; hence there are many different aspects influencing development of working life, which need to be considered. One of the most important community occupational health problems today is stress. On questioning workers regarding factors eliciting stress, "high work-load" was the most common response, followed by "short delivery time," "no influence at work," "no support from manager," "long working hours," and "worry about job security" (Kovacheva and Tang, 2003). The remedy for the dilemma we face is simple: change the manner in which the work is being done.

In developing countries of the West and Central Africa, death rates among workers are five to six times higher than those in industrialized countries (ILO Safe Work Report, 2007). Yet the phenomenon is still largely undocumented and there is insufficient political will to address the problem. Global competition, growing labor market fragmentation, and rapid change in all aspects of work create a mounting challenge for labor protection, especially in West and Central African countries. Workers in rural areas and the urban informal sector are often ignored or difficult to reach. These problems are mostly caused by suboptimal work situations, practices, and environments. Appropriate ergonomics, for a countrywide application, is urgently required in these regions.

21.3 Promoters of Ergonomics

Many ergonomists and organizations have attempted to meet the needs of IDCs by promoting the use of ergonomics to solve their problems (Wisner, 1985). The salutary work of the ergonomists in IDCs, people such as Hendrick, Kogi, Scott, Shanavaz, Wisner, and others has been reviewed. Their findings have one thing in common, i.e., with appropriate ergonomics interventions, there would be improvements in quality, productivity, working conditions, compliance with Occupational Health and Safety (OHS) standards, reduction of rejects and rejection costs, and increases in profit (Wisner, 1985).

21.4 Reflecting on Local Ergonomics Needs

The ergonomics needs for improving the working conditions and quality of life of the people in the developing countries of West and Central Africa are numerous and diverse. On the one hand, there is an increasing number of new work-related health risks such as musculoskeletal strain due to monotonous repetitive work, and exposure to hazardous substance have been brought into many workplaces associated with the most modem production technologies. Under such circumstances, cognizance needs to be taken of the adverse family and social effects due to the changes and to the increase in overtime and/or night and shift work. On the other hand, many people in the informal sector are struggling to earn daily basic necessities for supporting their families, so they put up with the numerous health risks associated with their work, such as excessive loads lifted and carried, and exposure to pesticides and other hazardous agents (Kawakami et al., 1999). Realistic support measures for establishing safer and more productive workplaces are urgently required. Our "West Africa Sub-Region: Ergonomic Needs Analysis" suggests that all the countries in this subregion need to focus on self-help initiatives using existing good examples as a base to start from, while Cameroon, Congo, Cote d'Ivoire, Ghana, Nigeria, and Senegal need support for basic tools and for the training of locals in order to generate sustained action. In addition Congo, Cote d'Ivoire, Ghana, and Nigeria need facilitators for the promotion of the basic concepts of ergonomics.

Dynamic and flexible approaches are required to improve working conditions in the West African subregion. The role of ergonomists is to provide multifaceted approaches, starting with an awareness of the actual conditions where the local people have to work. Practical ergonomics approaches to improve the safety and health of the workers are gaining momentum in many areas of this region. Learning from good local examples and developing practical ideas which are workable in the local context leads to success stories. The effort to promote ergonomics in Nigeria is creating positive results (Adaramola, 2005). The Nigerian government recently began to recognize that ergonomics is an essential tool that helps to improve workplace conditions and to enhance workers' safety. On this note, the Federal Ministry of Labor and Productivity through the National Productivity Center (NPC) has created a technical committee to oversee ergonomics activities.

On the international level the French Language Ergonomic Society was created to promote ergonomics in French speaking countries. A French ergonomics project was started after the Second World War, and culminated in its official birth in 1963 under the name of the Societe d' Ergonomic de Language Francaise (SELF). SELF supports or creates many initiatives in the field of ergonomics and initially worked to reinforce the link between French speaking ergonomics societies in order to organize meetings to discuss common problems and to build a network (Antonie, 2001). Developing ergonomics in countries which are not yet ergonomically orientated is also an important objective for SELF. In cooperation with this commission, the ergonomists in sub-Saharan countries organized a satellite seminar at the annual SELF congress in Aix-en Province in September 2002, dedicated to the different ways of conceiving work in these countries. Its aim was that some of their members (individuals born in these countries) should help to promote and develop an African approach to ergonomics that will take into account the specific type of work and organization in this part of the world. SELF hopes that new ergonomics societies will one day emerge in these countries.

21.5 Tools and Approaches in Ergonomics Studies in Field Conditions

There is growing recognition among ergonomists in West and Central African subregion that looking carefully at the working life of the local people is of particular importance in devising practical solutions. Though priorities differ locally across these regions, there are some similarities, and exchanges of information and more international collaboration will greatly help in solving existing work-site problems. Through such dialogue, one can begin determining which strategy is likely to be more beneficial and from whose perspective best practices should be considered. This can assist in the formulation of practical initiatives in working toward sustainability. Numerous ergonomics studies aimed at improving working conditions in IDCs have shared this practical approach; in addition, joint risk assessment methods, identifying necessary action points for the improvement and strengthening of local initiatives, have been developed and applied to many workplaces (Kawakami et al., 1999). As shown in Table 21.1, the ergonomic research tools for assessing the working life of the local people in different field conditions such as action checklists, direct observation of job content, and monitoring of workers' fatigue levels have proven useful in increasing local involvement. Using these practical field assessment tools, an increasing number of ergonomics studies in IDCs have identified the need for improvement. These field studies have usually produced practical recommendations for workable improvements suited to the local situation.

21.6 Ergonomics Intervention Strategies

Ergonomists, employers of labor, government labor inspectorate, ministry of health, local government agencies, and social services departments are all key players in

TABLE 21.1

Field Research Tools for Ergonomics Assessment

Research Tools	Purpose	Examples of Expected Results
1. Action checklist	Rapid identification of required ergonomics actions	Participatory action for low cost improvement
2. Time motion (direct observation)	Detailed ergonomics risk analysis	Quantitative analysis of postures and workloads
3. Fatigue monitoring	Knowing the patterns and nature of fatigue	Practical preventive measures against fatigue condition
4. Physiological indicators	Evaluating specific physiological responses	Supplementing the finding of direct observations
5. Questionnaires	Analysis of complaints and subjective assessments	Identifying priorities for ergonomics intervention
6. Time budget study	Understanding the living conditions of local people	Recommending redesign of work schedules
7. Group work	Mobilizing everyone's ideas for improvement	Identifying locally available solutions

Source: Kawakami, T. Jose, M.B., and Khai, T.T., *Industrial Health*, 37, 188, 1999. With permission.

applying ergonomics at national and local levels, and must have a real understanding of the particular needs of the country so as to be able to identify a suitable entry point for ergonomics interventions. The many strategies are based on the ILO (2007) Safe Work Global Program on Safety, Health and the Environment and include advocacy, building of a knowledge base, capacity building for constituents and support for direct action programs.

21.6.1 Showing That Protection Pays

The prevention of accidents, improvement of working conditions, and enforcement of standards are often seen as a cost to business. Little is known about the cost of not preventing accidents or of poor working conditions, or of the benefits of improvements in productivity. Better information and analytical tools would help increase the subregions' firms' and governments' willingness to invest in prevention. This strategy could then have two main thrusts: extending the ergonomics knowledge base through a major drive of comprehensive, reliable, and sustainable data, and new research on the ergonomics of labor protection.

21.6.2 Protection of Workers in Hazardous Conditions

Priority must be given to workers in the most hazardous occupations and sectors such as mining, construction, or agriculture, or where working relationships or conditions create peculiar risks. The subregion countries must be encouraged to be objective and target for the protection of workers in hazardous conditions. Particular attention could then be given to strengthening the advisory and enforcement capacity of labor inspectorates.

21.6.3 Extending Protection

From general observation, it is evident that the large majority of workers whose conditions are most in need of improvement are excluded from the scope of existing legislation and other protective measures in the subregion. Existing policies and programs need to be reviewed and extended to cover all workers. This will go hand-in-hand with action to strengthen the labor inspectorate's capacity to develop broad prevention policies and programs, and to promote the protection of vulnerable workers, particularly female workers. Alliances and networks can be extended to include ministries of health and industry, local government, education and social services, as well as local community groups. Emphasis should be placed on achieving tangible results through practical action and exchange of information on good practices among all the stakeholders in the subregion.

21.6.4 Promoting Workers' Health and Well-Being

The strategy to promote workers' health and well-being should involve the establishment of a data bank on policies, programs, and good enterprise-level practices so as to improve our capacity to identify worker protection issues and to provide guidance on new approaches. Government capacity for prevention, protection, and the application and enforcement of key labor protection instruments will then be strengthened.

21.7 Closing Remark

As an emerging profession in West and Central Africa, ergonomics is attempting to forge a lasting foothold in the subregion. The challenges are enormous. However, there is likely to be significant and gradual improvements in addressing all the subregions' needs, highlighted above, over time. A coordinated focus involving all the stakeholders is urgently required and West and Central Africa are just beginning.

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22

Ergonomics in South Africa, and beyond the Borders

Jonathan P. James and Patricia A. Scott

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22.1 Introduction

Ergonomics has a relatively short history on the African continent, but there is a growing awareness of the need for ergonomics, and many international and local enthusiasts have been actively involved in establishing the discipline in North, West, Central, and Southern Africa. Probably the first recognized practice of ergonomics in Southern Africa was conducted in the mines, with the internationally renowned work-physiology of Wyndham and Strydom in the 1960s investigating the effect of heat stress on miners working in some of the deepest mines in the world.

22.2 History of Ergonomics Society of South Africa

Although work of this nature has been ongoing in the mines since then, the concept of an ergonomics society was only put forward some 20 years later. Preliminary meetings were held at the Human Resources Research Laboratory, Chamber of Mines, Johannesburg in 1983 to discuss the path forward for ergonomics in the country. The next year, a meeting was held at the Design Institute in Pretoria, where a group was set up to address the feasibility of an ergonomics society in Southern Africa. The society was formally inaugurated in February, 1985 at the first Conference, "Ergonomics '85," which was held in the CSIR Conference Centre, Pretoria. The keynote speaker was Stuart Kirk, with Mike Cooke giving the inaugural address (both from Loughbourough University, United Kingdom). More than 40 papers were presented to over 100 delegates. During the conference, a general

meeting was held and the first council was ratified. Office bearers and committee members were elected; the first chairman was Tony Golding, with Jan van Tonder (vice chair) and Brian Hill (secretary) holding other senior roles.

Although the intent was to run a local conference every year, after the first three conferences in three years, the interest and support fluctuated. However, the drive of a few key members kept the society going, both internally and externally, and federated membership of the International Ergonomics Association (IEA) was a primary goal for this small, but active group of professionals working in the discipline. Regular submissions were made to the IEA over a period of 10 years. Mention must be made of the stalwart efforts of Brian Hill in his continued attempt to gain international recognition for the society, but politics ruled the day, and the Ergonomics Society of Southern Africa was not accepted as a Federated Society of the IEA until 1994. This was a turning point for the country politically, with a ripple affect on the society. Hal Hendrick (then president of the IEA) was the keynote speaker at the fifth conference, held in Grahamstown, and, with a modification to the name of the society, the Ergonomics Society of South Africa (ESSA) was finally accepted as a Federated member of the IEA. At this stage, membership was at an all time low, and fortunately the international recognition provided the boost the society needed to keep it going.

Initially ergonomics was predominately within the realm of academe, with postgraduate work under the guidance of Mike Cooke, George Jaros, and Bob Bridger at UCT, and the first full-time course was offered at Rhodes University in 1996 under the auspices of Pat Scott and Jack Charteris. With this commitment to developing the scientific discipline of ergonomics, there was a steady flow of international visiting professors who spent time at the universities, and also traveled round the country giving workshops and/or seminars to a cross section of industrial staff and Occupational Health and Safety groups on various aspects of ergonomics. With a growing awareness of ergonomics in the country, several other universities began offering short modules in ergonomics. This, plus the continued work at the mines means that some very good research was going on and there was a need for an outlet in the form of a local journal for this work to be published. Geoff Meese was the editor of the inaugural issue of *Ergonomics* SA (esa) in 1989, and although the quality of papers was good, the flow of articles was rather slow, with only a few from international authors. Pat Scott took over as editor in 1992, and once the society was internationally accepted there was an escalation of papers, both internally and globally as esa was promoted as a journal for international research being conducted in developing countries. The journal is now in the capable hands of Candice Christie (Rhodes University) and Andrew Thatcher (University of Witwatersrand).

22.3 Growth in the Society

The end of the 1990s were particularly good years for the society with membership growing substantially. In 1996, the IEA and ILO published their *Ergonomic Checkpoints*, and Houshang Shahnavaz and Pat Scott ran five successful Roving seminars around Southern Africa promoting this very useful handbook for applying basic principles of ergonomics within industries. Over the next few year numerous workshops on basic ergonomics, plus manual materials handling, and office ergonomics, were run by locals and international visitors in South Africa, Namibia, and Botswana.

The sixth conference "esa '96" was run in conjunction with Noshcon'96 at the World Trade Center in Johannesburg. In 1998, an IEA/ESSA Global Ergonomics Conference was held in Cape Town and was attended by over 250 delegates from 41 countries. This highly successful conference was the joint venture of Rhodes University and the University of Cape Town, and gave many keen local ergonomists a wonderful opportunity to interact with the international experts. It also put ESSA on the global ergonomics map. In 1998, Jon James moved us into the electronic age and developed an ESSA Web site, which is continually updated, making it interactive and a key platform for information delivery. The ESSA Web site has evolved over the past few years and is now located at www.ergonomicssa.com, attracting numerous hits from around Southern Africa and the globe. Members use the ESSA Web site to keep informed about society activities and IEA developments. In addition, members are encouraged to submit their own ideas for the site and to keep the rest of the membership updated about events happening in their regions. During the period 1999–2001, membership continued to grow. Pat Scott (ESSA chairperson) was elected to the IEA Executive Council, and was appointed as chairperson of the IEA Standing Committee for Ergonomics in industrially developing countries (IDCs). Pat worked hard on the promotion of ergonomics in South Africa specifically, and in IDCs generally. ESSA's image on the international scene was further enhanced with Andrew Thatcher taking over the organization of the International Cyberspace Conference on Ergonomics (Cyberg) which is an online conference using the WWW as a platform. Andrew organized the CybErg 2002 and CybErg 2005 events (joined by Jon James and Andrew Todd for the latter one) which were highly successful in encouraging discussion and debate over the Internet at the conference which was attended in a virtual environment (Thatcher and James, 2004). The CybErg concept has been widely embraced by many ergonomics professionals and students, particularly in Asia, and the 2008 event will be hosted by the University of Malaysia Sarawak (UNIMAS) in collaboration with Curtin University (Australia) and the University of the Witwatersrand (South Africa).

The early part of the new millennium was marked by fluctuations in the numbers of ESSA members. In an attempt to reach more people in a country made up of nine provinces with diverse languages, cultures, and interests, regional representatives were appointed to the committee, and were charged with the promotion of ergonomics within their region. In 2006, the ESSA membership met again at the CSIR Conference Centre in Pretoria for "esa '06," and the next year Candice Christie of Rhodes University organized the 10th conference at the International Convention Centre in Durban. More than 40 papers were presented at an outstanding event which attracted over 50 delegates.

22.4 Application of Ergonomics

Although much of this chapter has been about the academic aspect of ergonomics, it must be acknowledged that ergonomics is an applied science, and in a country such as South Africa there is a definite need to put much emphasis on the practical application of sound ergonomics theory at the "coal-face." Initially this was very evident with the research in the mines, and from the 1960s to today research has been conducted to improve working conditions in the mines (Schutte and Marx, 2007; Schutte et al., 2007). Another area where there was a good link between research and application was the work being done in the military in the 1970s and 1980s (Scott and Ramabhai, 2000; Christie and Scott, 2005).

But these were isolated pockets of specific research investigating problems in particular situations. However, in the last decade there has been a growing symbiotic relationship between industries and the universities as an increasing number of industries have recognized the need for ergonomics in their day-to-day running of the company, the most notable of these being the forestry (Scott and Christie, 2005) and automotive industries (James and Todd, 2003). The outcome has been reflected in a growing demand for ergonomists. It is encouraging to note that there are a number of ergonomics consultancies in the country, and several of the bigger companies are now appointing their own company ergonomists.

22.5 Challenges Facing ESSA in Africa

Unfortunately with the growing numbers of practicing ergonomists, who obviously are dependent on contracts to keep the money rolling in, there appears to be a rift between the academics and those working as consultants. It is crucial in a society as small as ESSA that this apparent dichotomy of interests be addressed positively as soon as possible. The bottom line is that we are all ultimately working to achieve the same outcome, namely improved working conditions in order to ensure efficient work practices and to enhance worker safety and well-being, while at the same time increasing productivity. There is an urgent need to establish a healthy, beneficial symbiosis between academics, practicing ergonomists, and occupational health and safety officers—all are crucial to the development of an ergonomics ethos throughout the country.

Associated with the above problem is an increasing number of charlatan ergonomists who are not qualified in the field, but are out there dabbling in ergonomics. Again in a country this size with a young society there is a need to work together to address the problem. With a limited number of professionally qualified ergonomists, we are working for a two-tiered level of practicing ergonomists: certified Ergonomists, meeting qualification criteria based on international standards and recognized globally; and in-house "Ergonomics Facilitators" who have attended ergonomics workshops and demonstrated a clear understanding of identifying problems, or potential problems, associated with their own job and are able to discuss possible solutions with employers and other employees within the company. The society puts out a regular newsletter bearing news of both local and international developments, and for several years had some "Useful Ergonomics Hints" for interested company laymen to implement in their companies. The more the society can do this sort of thing, the greater the understanding of ergonomics, and its benefits, will be. South Africa has promising academic and practicing ergonomists, the challenge now is to get them to work together as a cohesive unit for the good of ergonomics and the good of the country.

22.6 Aspirations

Having covered the development of ergonomics in South Africa, and made brief mention of other African countries, an achievable goal to aim for is an "African Ergonomics

Federation." It is clear that many isolated efforts are being made from north to south of the continent, and there can be no doubt that we all face similar problems. Maybe together we can offer more concrete assistance to improving working conditions of the millions of workers who are subjected to harsh, poorly organized work environments on a daily basis; in this way we can play a significant role in helping the continent become, not only more self-sustaining, but also a more viable contributor on the global market.

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Overview of Ergonomics in Latin America

Marcelo M. Soares

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23.1 Introduction

In Latin America, ergonomics took its first steps in Brazil in the 1960s. Since then, there has been a progressive development in the region. At present, there are various companies and research institutions which operate in several Latin American countries. The number of Latin American ergonomists at international conferences promoted by International Ergonomics Association (IEA) has been growing considerably recently and the number of papers presented represents the current status of ergonomics in each country. This chapter based on Soares (2006) offers a brief overview of ergonomics in Argentina, Brazil, Chile, Colombia, Mexico, and Peru. It includes a short description of the history of ergonomics in each country, the training of ergonomists, ergonomics teaching, the areas of interest of ergonomists, and the professional practice of ergonomics. Thus, it aims to archive the evolution of ergonomics in Latin America, and to assist with the development of policies toward cooperation, ergonomics development, and mutual support among the several South American associations of ergonomics.

23.2 Ergonomics in Argentina

According to Poy et al. (2006), the development of ergonomics in Argentina has been problematic and limited to isolated groups and companies since its beginning. The theme of

'quality improvement of life' in the workplace has been neglected due to issues such as industrial reconversion processes, privatization, and inflation control (Hiba, 1991). As observed by Poy et al. (2006), there is now undoubted evidence of a renewed interest in ergonomics, and in particular, the analysis of work activities. The author also highlights that, although there is a strong interest in ergonomics within educational institutions, ergonomics has not yet been institutionalized in this country, by way of a well-defined profile.

The first demonstration of interest in ergonomics dates from 1950, but it was not until 2002 that the Ergonomics Association of Argentina (ADEA) was founded. In due course, it became federated to the IEA and a cofounder of ULAERGO together with the associations in Chile, Brazil, Colombia, and Mexico. ADEA is organized into committees whose priorities currently are to obtain international ergonomics certification as an independent profession, to publicize ergonomics through the Web (www.adeargentina.org.ar), and to mount public events. A resolution in 2003 defines the scope and objectives of ergonomics within the Prevention of Risks at Work, which incorporate those previously included such as "musculoskeletal disturbances." This resolution also incorporates directives which lay down maximum limits for repetitive movements and lifting loads. At present, the work of ergonomists in Argentina is found mainly at the universities and companies in various industrial sectors such as Peugeot, Fenix, Volkswagen, Ford, Arcor, Kraft, Petrobras, food, and workplace risk insurance companies.

In Argentina, ergonomics teaching is currently offered in two postgraduate courses of 500 h, at the IRAM—Instituto Argentino de Normalización y Certificación (Argentinian Institute of Standards and Certification) and UTN—Universidad Tecnológica Nacional (National Technological University), in Buenos Aires. Furthermore, the subject of ergonomics is taught (1) in undergraduate courses in industrial design, industrial engineering, kinesiology, physiology, and psychology; and (2) in postgraduate courses (masters and doctorate levels) in occupational medicine, hygiene and workplace safety, social science of work, and kinesiology. An example of developments in the discipline of ergonomics in Argentina is the study carried out by Neffa et al. (2005) on the impact of corporate tele-training on workers' health. Finally, the growing number of agreements for cooperation and exchange with scientific–academic institutions, both at the regional and international levels, has resulted in the exchange of experience, translation of publications, participation at congresses and seminars. Such activities contribute to the progressive development of ergonomics in the country.

23.3 Ergonomics in Brazil

The dissemination of ergonomics in Brazil has been established, according to Moraes and Soares (1989), through six main episodes:

The "first" episode took place in the 1960s, in the Polytechnic School at the University of São Paulo, with the introduction of studies related to ergonomics in the Manufacturing Engineering course.

The "second" episode took place at the beginning of the 1970s, at the Federal University of Rio de Janeiro, with the introduction of ergonomics teaching in the postgraduate course of Manufacturing Engineering. In 1978, the first book on ergonomics written by a Brazilian author was published, *Ergonomia: notas de classe* (*Ergonomics: Class Notes*), by Professor Itiro Iida. In 1971, the first doctorate thesis in ergonomics was defended in Brazil, at the University of São Paulo. The thesis, by Professor Itiro Iida, was entitled *A ergonomia do manejo* ("The ergonomics of handling").

The "third" episode was located at the College of Industrial Design, at the State University of Rio de Janeiro, with the introduction of ergonomics teaching, in 1976, in the Industrial Design course, according to the model of the Ülm School, in Germany. Following this experience, ergonomics became a compulsory subject in industrial design courses across the country. It is also important to mention that this distinctive feature marked the emphasis of Brazilian ergonomics on design. It was only in the last decades that the international literature has registered the relationship designated "ergonomics and design."

The "fourth" episode was identified through the studies related to ergonomics psychology, with the emphasis on visual perception concepts applied to the study of traffic—training of drivers and studies of motorway accidents at the University of Sao Paulo, on the Ribeirão Preto campus.

The "fifth" episode took place at the Higher Institute of Studies and Psychosocial Research of the Getúlio Vargas Foundation, in Rio de Janeiro. In 1974, this institution organized the 1st Brazilian Ergonomics Seminar, hallmark in the history of Brazilian ergonomics, and in 1975 implemented the first Specialization Course in Ergonomics in Brazil. This course was taken by several ergonomists who are currently teaching in various courses and working in the setting up of ergonomics groups within companies and academia.

The "sixth" episode was marked, still in the 1970s, by the visit of Professor Alain Wisner from the *Conservatoire National des Arts et Métiers* in France. Professor Wisner became a great supporter of Brazilian ergonomics and was responsible for the education, at postgraduate level, of various Brazilian researchers who are currently responsible for the development of several research studies and postgraduate programs at Brazilian universities. The academic cooperation between Brazil and France resulted in a strong influence of French ergonomics in the practice of a great number of Brazilian ergonomists. Moraes (2002) states that British ergonomics lost its opportunity to influence Brazilian ergonomics due to the lack of any strong link between either British, American universities or Brazilian universities in this field.

In Brazil, ergonomics is currently a module taught in hundreds of graduate and postgraduate courses in the fields of industrial design, architecture, manufacturing engineering, occupational therapy, odontology, and psychology. Although ergonomics has already been consolidated, academically speaking, in Brazil in the masters and doctorate courses, the professional training of the ergonomists, who do the fieldwork, takes place through specialization courses of at least 360 contact hours. At present, there are several consultancies of ergonomics in Brazil and a great number of ergonomists working for private and governmental companies in various areas, such as metallurgic, steel, civil engineering, aviation, informatics, and energy industries.

The Brazilian Ergonomics Society (ABERGO)—www.abergo.org.br—founded in August 1983 has currently about 350 members from all regions across the country and from diverse educational backgrounds: business administration, architecture, social service, biology, industrial design, nursing studies, various engineering domains, physiotherapy, medicine, psychology, and occupational therapy. Fourteen congresses in ergonomics have taken place in Brazil, attended by around 600 participants and an impressive number of international guests. The congresses are currently held every two years. Soares (2005) had updated his inventory, based on the proceedings of Brazilian Congresses in Ergonomics between 1999 and 2008, and stated that the most well-researched fields in ergonomics in Brazil are industry ergonomics, product ergonomics, hospital ergonomics, ergonomics and services, ergonomics and the building environment, ergonomics analysis of workplace, biomechanics, ergonomics and accessibility, ergonomics design, informational ergonomics and human computer interaction (HCI), and Ergonomics and Work Safety.

In 2002, ABERGO created the Certification System of Brazilian Ergonomist, which was the first experiment in certification of ergonomists in Latin America. In September 2004, the first Brazilian ergonomists were awarded their certificates. There are currently 83 certified ergonomists in Brazil. The certification of groups and companies and the accreditation of specialization courses in ergonomics are scheduled to take place shortly.

Brazil currently occupies a hegemonic position in Latin America ergonomics and a renowned place compared to other Portuguese- and Spanish-speaking countries. ABERGO has been affiliated with IEA since 1991. In Brazil, the National Council of Ergonomics is the assistant agency to the Ministry of Labor and Employment on issues related to this field of knowledge. The Regulating Act No. 17 of the Ministry of Labor and Employment regulates ergonomics practice in the country.

23.4 Ergonomics in Chile

Chilean ergonomics has been carried out through various laboratories of ergonomics, which have developed relevant work across the country. The first of them, later called Ergonomics Unit, was set up in 1972, at University of Concepción (Figueroa, 2002). This Ergonomics Unit developed pioneering work with the fishing, mining, and manufacturing sectors, with special mention of the work in the forestry industry, which has international recognition. Besa (quoted in Figueroa, 2002) reports on the analysis of the first cases of tendonitis and "tenosynovitis" in the Chilean Safety Association Company, in 1985, carried out by a multidisciplinary team. In 1987, the same team set up the Ergonomics Laboratory at the Catholic University of Chile which carried out work together with CEPAL, the United Nations agency in Chile; ergonomics analysis of the underground in Santiago. In 1992, the Ergonomics Laboratory finished its activities. Since 1988, the Ergonomic Centre and Workplace Studies (CEYET) started carrying out specific investigations of work in the copper mines. Since its inception, this center has become a meeting point for exchange among Chilean ergonomists.

At present, some companies already hire their own ergonomists, as it is the case of the Chilean Safety Association, Institute of Workplace Safety, and Mutual de Seguridad. There are also several consultancy companies in the country. Pérez (quoted in Figueroa, 2002) carried out a study to identify the rate of dissemination of ergonomics in the educational institutions in Chile, and concluded that ergonomics was taught in several graduate courses: design, forest engineering, industrial project engineering, odontology, psychology, and occupational therapy. Postgraduation diplomas, consisting of 300 h courses, are offered at University of Concepción and the University Gabriela Mistral.

The National Ergonomics Commission, an agency of the Ministry of Labor and Welfare, is involved in the study and regulation of heavy work. There are various rules for ergonomics in Chile, including visual warning information, thermo commodity, evaluation of posture for static work, school furniture, and information technology. The Chilean Ergonomics Society (SOCHERGO)—http://sochergo.ergonomia.cl/—was founded on 30 September 1988 and has 35 members to date. The Board Meeting of IEA took place in September 2002, and at the same time the ULAERGO—the *União Latino Americana de Ergonomia* (Latin America Ergonomics Union)—was founded in Santiago. For more detail about ergonomics in Chile, refer to Chapter 24.

23.5 Ergonomics in Colombia

Ergonomics is in its early stages in Colombia in the field of risk prevention in the workplace through consultancy services contracted by Professional Risk Business Companies. In the past couple of years, these companies, on their own initiative, have carried out ergonomics diagnostic tests to bring about changes in work activities. The Colombian Ergonomics Society (SCE)—www.scergonomia.com—was set up in May 1996 at the 1st Colombian Congress of Ergonomics, which was attended by 240 participants. Although still young, the SCE has already made important contributions to Colombian ergonomics, such as its representation as a scientific society on the National Committee for Occupational Health; its acknowledgment as the assistant agency to the Ministry of Social Protection; its participation, along with the Ministry of Social Protection, in policy making for the development of ergonomics in the country; the formulation of juridical norms of technical character for ergonomics in the country; the hiring, on the part of the Colombian Petroleum Company—ECOPETROL, for the creation and validation of directives on the company's ergonomics nationwide.

In addition to the 1st Colombian Congress of Ergonomics, there have been four other congresses of ergonomics. The last one took place at Medellin, in 2004, with the theme of "Ergonomics and the transfer of technology." At present, the educational provision for ergonomists in Colombia is concentrated in two specialization courses in ergonomics at the University of El Bosque, in Bogotá, and at the University of Antioquia, in Medellín. The scientific research work in ergonomics is concentrated in the academic setting, both at the graduate and postgraduate levels, in the following fields: ergonomics, occupational health, and prevention of workplace risks. The majority of the studies are related to physical ergonomics.

During 2007, the Colombian Ministry of Social Protection, with the cooperation with several Colombian ergonomists, developed a "National plan for the prevention of musculoskeletal disorders." This plan was created because musculoskeletal disorders are the most common occupational disease in Colombia. The first step of this plan will be implemented at the end of 2008. This Ministry, in association with several Universities and Colombian ergonomist, has developed three Evidence-Based Medical Guidelines for the most common musculoskeletal disorders in the country: low back pain, upper arm musculoskeletal problems (including carpal tunnel syndrome), and shoulder pain. Nowadays, the number of professionals who have studied ergonomics abroad is growing in Colombia. These masters and doctoral-level professionals will increase the development of ergonomics in Colombia in the future, and the creation of a Master of Science in Ergonomics is planned by several universities within the country for 2009. Also, in association with the Colombian Institute for Technical Standards and Certification (ICONTEC), Colombia is developing more than 15 Ergonomics standards, some of which will be published at the end of 2008.

23.6 Ergonomics in Ecuador

It is only very recently that Ecuador has experienced professionals who offer studies, consultancies and programs in ergonomics, and most companies only know of the term and less about the importance and benefits of ergonomics. There are very few professionals

who practice ergonomics in Ecuador, most of these being in the large cities such as Quito, Guayaquil, and Cuenca. This is due to the fact that most companies prefer evaluation programs concerned with environmental risk, and place ergonomics in a secondary position. However, recently multinational companies and others involved in large-scale production for export (such as floriculture, shrimp-farming, bananas, and other food products) are asking for professionals to conduct consultancies and ergonomics programs. The Ecuadorian Institute of Social Security, with its Department of Risks at Work, has since 2007 required the implementation of ergonomics by companies in compliance with the law.

The Ecuadorian Association of Ergonomics was founded in May 2007 and submitted its application for membership in the IEA in 2008. Since its foundation, the EEA has already held three seminars for its associates. The EEA has publicity campaigns so that all public and private bodies can have programs of ergonomics.

23.7 Ergonomics in Mexico

The development of ergonomics in Mexico has sprung from two sources. The visit of Professor Nils Lundgren in 1970, sponsored by the *Centro Nacional de Productividad*, which encouraged the interest in the field and the publication of various materials on the theme, and the setting up of the Association of Ergonomics which worked precariously for a few years and died out shortly after that, but was restarted in 1997. Thus, The Ergonomists Society of Mexico (SEMAC)—www.semac.org.mx/—was refounded in May 1997. In November 1999, to mark the anniversary of the Mexican Revolution, the 1st International Congress of Ergonomics was held at Monterrey. Since then, the SEMAC has offered seven annual congresses of ergonomics; the last one in November 2005 at Monterrey, Nuevo Leon. In 2001, SEMAC was recognized as a federated member of the IEA. At present, SEMAC has 105 members, including engineers, doctors, designers, psychologists, and business administrators.

Currently, there are very few ergonomists in the vast majority of companies in Mexico. Ergonomics work is performed by engineers, doctors, or designers. Since 1974, the establishment of graduate courses in industrial design has generated a great interest in the field of ergonomics. Ergonomics teaching is offered through a few modules in courses on industrial design, industrial engineering, and psychology, mainly in the universities at Guadalajara, Cidade do México, and Monterrey. In the past year, the SEMAC has cooperated with the Secretariat for Labor and Social Prevention to review ergonomics norms.

23.8 Ergonomics in Peru

The Peruvian Society of Ergonomics (ASPERG) was created in June 2006 by a group of professionals who belonged to the Center for Risk Prevention of social security of Peru. A few meetings have been organized with the support of the International Labor Organization, the Institute for Labor Health and local universities. The ASPERG has hosted three annual meetings and a few basic courses in ergonomics to date. In professional terms, there is not yet any legislation on ergonomics in Peru. A few multinational

companies carry out intervention related to the evaluation of workstations. Although there is no educational provision for ergonomists in Peru, the subject is offered in the Master programme in Occupational Health at the National University of Center Peru (UNCP).

23.9 Ergonomics in Venezuela

Ergonomics in Venezuela is still in its infancy as it has only been recognized since 2005 following the enforcement of legislation which referred to this scientific discipline. Teaching ergonomics in Venezuela takes place as a discipline in undergraduate courses in Engineering and Industrial Relations and in the Master's program in Occupational Health. Scientific investigations in ergonomics in Venezuela are undertaken in laboratories of the Universities of Carabobo, Zulia, Táchira, Los Andes, and Rafael Belloso Chacín in the city of Maracaibo. They are also conducted in the Center for Investigations of Human Factors and the Laboratory of Ergonomics of the Faculty of Industrial Engineering of the University Andres Bello de Caracas.

The Venezuelan Union of Investigators in Ergonomics and Occupational Health—UVIERSO (the Union's acronym in Spanish)—was created in March 2007 in the presence of research staff from the universities of Zulia, Los Andes, Carabobo, Táchira, and Rafael Belloso Chacín. In June 2008, the first Seminar in ergonomics was held at the University Rafael Belloso Chacín, in Maracaibo, and the first. Venezuelan Congress on Ergonomics and Occupational Health was mounted in the city of Valencia, in December 2008.

23.10 Conclusion

Ergonomics has faced many challenges in Latin America. With the exception of Brazilian ergonomics, which has shown a consistent development since its inception, it was observed that Latin American ergonomics is a field which has not yet been fully consolidated. One of the main reasons has been the lack of postgraduate programs at the level of Masters and Doctorate degrees, which may have hindered research in the majority of countries included in this report. The implementation of postgraduate courses, in particular the specialization courses which qualify ergonomists for the market, constitutes a challenge to several countries in Latin America.

The professional practice of adequately qualified ergonomists may lead to a Certification System appropriate to each country. The successful experiment in certification such as the one developed by Brazilian ergonomists may provide a model to those countries. The Latin American Ergonomics Union (ULAERGO)—http://ulaergo.ergonomia.cl/—established as an affiliate of IEA, has become a leader in scientific development, cooperation, dissemination, and implementation of Ergonomics on the continent. In the future, ULAERGO may become a catalyst for change in Latin American ergonomics, assisting in the formulation of common policies among the country members, which in turn can trigger development and cater to diversity among the people of these diverse regions. Through ULAERGO and the cooperative work of the various ergonomics associations, the successful experiences may be replicated and good practice disseminated across the continent.

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24

Ergonomics in Chile

Elias Apud and Felipe Meyer

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24.1 First Steps

This chapter summarizes part of the experience acquired in Chile, after more than 40 years of research and teaching to improve the working environment of Chilean workers. It is impossible for the authors of this chapter to give a complete review of the development of ergonomics in Chile. However, although much of the information presented is personal, it is also based on the main source of information available in the country, which is a compilation carried out by Figueroa (SOCHERGO, 2002).

The first attempt to introduce ergonomics in Chile started in 1965 at the National Institute of Occupational Health in Santiago, the capital of the country. This was partly motivated by a legal decree which allowed workers to be pensioned one year earlier for every five years of involvement in heavy manual work. In those days, there was very little knowledge on how to differentiate the intensity of work, particularly aspects related to physiological workload and heat exposure. Dr. Hugo Donoso, medical doctor and physiologist, was the first in the country to develop studies to establish objective criteria to qualify the intensity of work. Although his name is not very often quoted, it is fair to say that Dr. Donoso is the real father of ergonomics in Chile. Methods to evaluate the physiological workload were well developed, but he and his group found that it was not enough to determine only if work was heavy or not, as a worker who may have been pensioned early would still have had to endure 30–35 years of heavy or extremely heavy work. Hence, the idea to reduce the workload according to the capacities and limitations of Chilean laborers was identified as a very important goal. Therefore in 1968, Professor Nils Lundgren, a Swedish Medical Doctor and Ergonomist, was invited to Chile as a World Health Organization consultant in ergonomics. He spent four months in the country carrying out applied research and teaching at the National Institute of Occupational Health. The field work organized by Donoso, Lundgren, and a multidisciplinary team of young scientists was a real example of good research, and many of the methods introduced in those days are still in use (see Donoso et al., 1971; Apud et al., 1972). After Professor Lundgren left Chile, a research group

was organized to continue his pioneer work and a few young scientists went abroad to study ergonomics, mainly in Sweden, England, and France.

In 1972, the University of Concepcion started a laboratory originally called "Biology of Effort," in the Faculty of Biological Sciences. Shortly after the initiation of teaching and research activities, the name was changed to the "Unit of Ergonomics." It was the first institution in the country fully devoted to promotion of teaching and research in Ergonomics and therefore the history of the discipline in Chile is closely linked to the pioneer work carried out at the University of Concepcion, which is located 500 km from Santiago. In the beginning, with limited human and material resources and continuing the work started in Santiago by Dr. Donoso, it was necessary to establish priorities. Industrial work, traditionally performed using labor-intensive methods, was progressively evolving toward capital-intensive methods. In those days, it was possible to predict that both forms of work would coexist in the years to follow, as indeed proved to be the case. In that respect, attention was paid to the improvement of manual work, but at the same time interventions were extremely important to insure that the mechanization process was ergonomically sound.

Because of the importance of labor-intensive methods, the studies performed in the first six years after the birth of the Unit of Ergonomics were devoted to increasing the understanding of the physical characteristics of Chilean workers and their social and working environment. There was also a need to quantify their food intake and habits in relation to the energy expenditure of heavy activities, particularly in mining and forestry. In addition, an effort was made to improve manual methods with the aim to reduce the workload and to increase the efficiency. However, these were not the only aspects influencing manual work. There were a number of organizational factors which had to be considered such as housing, nutrition, hygiene and recreation in the mining and forestry villages and camps, as well as safety, organization of team work and basic training. In other words, it was necessary to face the problems of heavy manual labor trying to integrate all factors which could improve worker well-being, keeping in mind that to motivate changes in industry they had to be associated with an increment in labor efficiency. Together with the work physiological developments, the first anthropometric and biomechanics studies were carried out in the country which, by 1995, had provided a database of body size based on a sample of nearly 4000 male and female Chilean workers.

Although it was expected that growing expertise in the area of manual and mechanized work would lead to well-designed jobs, effecting change in practice was a difficult task. Planners, managers, and engineers were not easy to convince. Their aim was to keep production at the highest possible rate with the lowest cost, and with the means that were available. As human beings are flexible, and in developing countries labor is cheap and easily available, managers did not pay much attention to working conditions. Having to face this fact, the first step was to promote knowledge about the aims of ergonomics. In the 1970s, attention was given to extension work and also to academic teaching. One important fact that helped the promotion of ergonomics was the introduction of curricular ergonomics courses for undergraduate students of Forest and Industrial Engineering at the University of Concepcion. This increased the feedback to industries, and part of the initial difficulties experienced in reaching managers was progressively reduced.

In Santiago, and parallel to the activities of the University of Concepcion, under the leadership of Horacio Rivera, Jorge Sanchez, Soledad Larrain, and a group of young scientists, an interesting job was done to get support from universities and also from

state agencies and insurance companies (called "Safety Mutual"), who were in charge of the administration of the law for the protection of workers against accidents and occupational diseases. One important outcome in 1987 was the creation of a Laboratory of Ergonomics at the Catholic University in Santiago, which started very promisingly, but unfortunately after a few years of good work was closed. Then, as a means to keep ergonomics going in Santiago, Horacio Rivera started a consultant firm called "CEYET." Since 1988, he and his colleagues have made a significant effort to promote ergonomics in Chile. They conducted extensive research, particularly in mining, and also encouraged teaching activities. In those days, CEYET was a point of encounter where the first discussions took place to organize the "Chilean Ergonomics Society." Finally, in January 2000, the ideas developed many years before gave legal birth to the "Sociedad Chilena de Ergonomia" (SOCHERGO). The first president was Horacio Rivera, followed by Maria Eugenia Figueroa and Miguel Acevedo. It is important to highlight that under the presidency of Maria Eugenia Figueroa, with Paulina Hernandez acting as general secretary, SOCHERGO had a significant growth. As a matter of fact, thanks to their initiative, SOCHERGO became a federated member of the International Ergonomic Association (IEA).

24.2 Ergonomics Today

A number of Universities have started ergonomics courses for undergraduate students from different disciplines (SOCHERGO, 2002). Special mention deserves to be made of the work carried out at the University Andres Bello by the ergonomist Georg Bialoskorski and by Victoria Ratinoff at the "Technological Metropolitan University" who have introduced ergonomics courses for students of Industrial Design.

On the other hand, the four "Safety Mutual" companies, three private and one a state agency, have organized departments of ergonomics which are helping increase interventions in industries. The Ministry of Health and the Ministry of Education have also encouraged research, mainly focused on the prevention of muscular and skeletal disorders, while the awareness of the Ministry of Labor in topics related to heavy work has culminated in a permanent group called "Comisión Ergonomica Nacional" (CEN), technically responsible for the classification of work with the purpose of identifying the need for an earlier pension. The guidelines for the evaluation of physiological and psychological factors, plus environmental and organizational aspects which are at present considered for the classification of work, are contained in a book requested by CEN to the University of Concepcion (Apud et al., 2002). Although several Universities teach ergonomics, only a few of them are carrying out research. In this connection, the investigations carried out in the Chilean forest sector have been well evaluated by international bodies. For example, the ILO published two books describing the Chilean experience which have been used as basic material in various developing countries and also in at least one industrialized country, namely Sweden (Apud et al., 1989; Apud and Valdes, 1995).

Another important achievement is the provision of postgraduate programs. Three universities, Universidad Mayor, Universidad de Santiago, and Universidad de Concepcion now offer course of about 300 h at the level of diploma. It is important to mention that one of those courses, at the University of Concepcion, is online with a period of residence for practical work. This is facilitating integration with other Latin

American countries and up to the present day students from Argentina, Uruguay, Colombia, Venezuela, Ecuador, Peru, and Brazil have been trained in Chile. Finally, also related to teaching, the growth of the discipline was reflected in the implementation of a Master's course at the University of Concepcion, which is in its first version with 25 students. This is the first such program offered by a Latin American University.

The current president of SOCHERGO is following the excellent job done by the past president, Maria Eugenia Figueroa, to make Chilean Ergonomics part of the international community. The Web page of SOCHERGO (http://sochergo.cl), as well as a communication net organized by Dr. Miguel Acevedo, has been very well received by Spanish-speaking specialists and is also becoming a useful tool for young students who search for advice.

24.3 Future Challenge

There are three aspects which have to be reinforced in the future. First, it is almost mandatory to continue improving the quality of research. As a countryman writer said, Chile has a "crazy geography"; more than 4000 km length, with different climates, spread along a narrow strip of land, and the Chilean laborer carries out work under conditions which fluctuate between operating in the driest desert in the world and the icy and cold Antarctic land, not to forget fishing along the Pacific coast, and mining at very high altitude in the Andes mountains. This reveals the need to encourage research to define limits for performance under extremely demanding conditions. Of course, this is in addition to common practices found in industries and agriculture. There is a big need to close the gap between studies diagnosing the problems found in these diverse conditions, and participatory ergonomics interventions aimed to improve the quality of working life. At the same time, being technologically dependent, it is fundamental to include ergonomics in new investments. From this point of view, there are initiatives which are being developed in the big copper mines, the primary source of income of the country, to incorporate ergonomics at the early stages of project development.

The second aspect is the need to continue improving teaching at all levels. At present, the dearth of knowledge in business enterprises, as well as the commercial opportunities to conduct "fly-by-night" ergonomics courses, is hampering our consolidation of the discipline, and there is an increasing number of so-called "specialists" in "chairs and tables" which will not help solve the problems being faced by Chilean workers, and which discredit the real aims of ergonomics. Therefore, SOCHERGO is playing an important role in the implementation of a certification system, which is at present under discussion and hopefully will be ready in the near future.

Finally, the laws for the protection of worker health and safety have to be improved. For example, law 19.404, which allowed the earlier pension for long-term manual laborers required to do hard physical work, does not consider any corrective measures and this needs to be reviewed. It is not fair for a person who keeps doing heavy work for 30 or more years, even if the workload is well documented. In this respect, ergonomics can help to improve the legislation because, recognizing that in Chile there are many occupations which are carried out under extreme conditions and as a consequence these workers deserve an earlier pension, there are many more jobs that could benefit from ergonomically sound interventions aimed at reducing the physical, mental, and environmental workloads of the workers.

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25

Ergonomics in the People's Republic of China

Pei-Luen Patrick Rau and Tom B. Leamon

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25.1 Level of Development

25.1.1 Current Situation

In the 1980s, China's development started from the coastal areas; in the east the cities of Shanghai, Jiangsu, Zhejiang, in the south Fujian, Kuangdong, Hainan, and in the north Beijing, Tianjin, Hebei, and Shangdong. After two decades, the development disparity had grown between these coastal areas and other areas in central and western China. The costal areas with 36% of the population contribute 56% of the country's gross domestic product (GDP), 58% of the manufacturing industry, and 57% of the service industry. The average GDP of the three coastal areas is 23,697 Yuan (about 3400 USD) per person, which is 1.7 times of the country's average (Wen, 2007). The Chinese government, while supporting the growth of these coastal regions, is seeking to balance the development by speeding up development in other areas.

Beijing, Shanghai, and Guangzhou (Shenzhen) are the three major cities playing an important leading role in each of the three coastal areas. Beijing, as the capital, is the political and cultural center of China and the potential economic development of Beijing is generally considered second only to Shanghai. Beijing's service industry is bigger than

that of Shanghai and the Zhong Guan Village in Beijing is considered to be China's Silicon Valley. Shanghai, located in the center of the eastern coastal area, is the largest economic center in China, with exceptional international links and a growth of production which is the highest among all provinces and cities in China. The southern coastal area, the Zhujiang Delta, where Guangdong developed first in the economic reforms of the 1980s, includes Hong Kong, Shenzhen, Guangzhou, and Dongguan, and constitutes the center of economic growth. The manufacturing industry in this area produces the low-priced "MADE IN CHINA" products recognized throughout the entire world.

With the advantage of geographical location and government support, the coastal areas have developed rapidly and, for the last 20 years, the labor-intensive manufacturing industry has been the main driving force behind regional economical growth. To meet the demand for labor in these three regions, large numbers of migrant workers* have moved to work in the manufacturing, construction, and service industries, and have made a major contribution to the development of the three coastal areas' competitiveness. The proportion of migrant workers is very significant: 68% in manufacturing, 58% in construction, and 52% in the service industries (CPCFW, 2007). Clearly, migrant workers have become the most important group of the labor force.

25.1.2 Future Development

The 11th five year plan for national economic and social development (*People's Daily*, 2006) sets forth the main targets of economic and social development:

- GDP growth to be about 7.5% annually. Both urban employment and migrant workers will increase to 45 million.
- Registered urban unemployment will remain under 5%.
- Proportion of added value in the service industry to GDP will grow by 3% and R&D expenditure will increase to 2% of GDP.
- Energy consumption per unit of GDP to decrease by 20% and water consumption per unit of industrial added value to decline by 30%.
- Urban and rural development is to grow in a balanced way with urbanization rate growing to 47%.
- People's average education to increase to 9 years.
- Urban basic pension insurance to cover 223 million people and the new rural cooperative medical care coverage to reach over 80%.

25.2 Development of Ergonomics in China

Ergonomics is gaining more and more attention in both the work environment and normal living. While human–computer interaction has received much attention with the development of information technology, and (because of domestic and international pressure)

* Migrant workers are usually Chinese citizens, relocating within China, usually from rural to urban environments.

the manufacturing industry has invested resources in occupational safety and health, the majority of the manufacturing work force (migrant workers with limited education and training) is working without protective equipment and facilities. This provides both a challenge and an opportunity for ergonomics.

25.2.1 Migrant Workers

The significance of the migrant work force cannot be underestimated and the government, committed to the concept of a "harmonious society" for political, social, and humanitarian reasons, is constantly seeking to address the many issues surrounding this labor force.

25.2.1.1 Migrant Workers' Demographics

The phenomenon of migrant workers originates from the excess of human-power in villages, low incomes in agriculture, and the demand created by industrialization and urbanization. The surplus human-power in the countryside has reached approximately two-thirds of the total human-power, causing workers to move to nonagricultural industries in or near cities. In 2004, there were about 120 million Chinese migrant workers in the large cities (CPCFW, 2007). If migrant workers employed in small cities and elsewhere in the countryside are included, the total number may reach as high as 200 million. The official definition of migrant workers refers to those with household registration in villages, but who are primarily engaged and earning their income in nonagricultural industries. These migrant workers are mainly young adults with a junior high school education. In 2004, 16–30 year old migrant workers accounted for about 61% of the labor force, the 31–40 year olds make up about 23%, and 41 year olds and above accounted for 16%. The average age of these workers is 28.6 years, and 66% have studied or completed a junior high school education; but only about 24% of them have received training in work-related skills (CPCFW, 2007).

The majority of these workers come from central and western China: in 2004, there were over 47 million migrant workers from central China and 31 million from western China, accounting for about 40% and 27%, respectively, of the total. Migrant worker employment is primarily in the manufacturing, construction, and the service industries. In 2004, 30% migrant workers were engaged in manufacturing, 23% in construction, and 10% in the service industry, while another 7% worked in the hospitality industry, and 5% in the wholesale and retail domains. Migrant workers usually work in the larger cities of east China where there are more opportunities and higher pay; 82% of these workers work in just seven cities: Beijing, Tianjin, Shanghai, Zhejiang, Jiangsu, Guangdong, and Fujian (CPCFW, 2007). Most migrant workers wish to stay in these cities but many cannot register as residents of the cities where they work due to government policy. Therefore, these migrant workers are like migratory birds, moving year after year between their hometown and place of work. Some only go home for long holidays and some only leave home during off-seasons.

25.2.1.2 Migrant Workers' Lifestyle

Migrant workers' jobs and working environments vary significantly, but in most cases their working conditions are poor due to ignorance of work safety. Migrant workers' wages are low and many work in jobs which require intensive physical loads in dangerous and polluted environments including construction, mining, processing of toxic chemicals, and sanitation. Excessive overtime and heavy work are very common, some working

11 h per day, and over 26 days per month (CPCFW, 2007). Moreover, employers of such workers often use old, outdated, and unsafe machines and equipment, and their workers are exposed to poor conditions with noise, dust, and noxious gas exceeding acceptable standards. The result is a high proportion of occupational diseases and work-related injuries: 51% of migrant workers indicate that their workplaces have unprotected equipment and facilities, 14% indicate that their employers do not provide basic protective equipment, and 19% indicate that their employers do not improve bad air or hot conditions to avoid heatstroke (National Bureau of Statistics of China, 2006). Almost 700,000 workers are disabled each year due to work-related injuries—migrant workers being the majority. In the coal mining industry alone, which employs mainly migrant workers, more than 6,000 workers died in a single year (CPCFW, 2007).

The social security status of most migrant workers is poor, some employers illegally ignore insurance for migrant workers, and the migrant workers' knowledge and awareness of their rights are limited. An investigation by the Ministry of Labor and Social Security indicated that the percentage of migrant workers covered by medical insurance is about 10%, the percentage buying a pension is about 15% and for work-related injury only 13% are covered by insurance (CPCFW, 2007). In order to keep their jobs, migrant workers tend not to confront employers for their rights.

25.2.1.3 Central Government Concerns about Migrant Workers' Safety and Welfare

The China State Council pays special attention to the health and safety of the migrant workers and requires all levels of government to take measures to help migrant workers. The report "China State Council's Opinions about Solving Migrant Workers' Problems" (China State Council, 2006) outlines the State's approach to work safety and health:

- Local governments should follow national regulations and standards of the State Administration of Workplace Safety Supervision.
- Employers must provide necessary protective equipment and facilities.
- Both government officers in charge of work safety as well as safety personnel in enterprises will be investigated following any serious accident.
- Migrant workers engaged in high-risk operations must receive the necessary training and required certificates. Employers must buy appropriate and required health insurance policies for migrant workers' work-related injuries and diseases, and help injured migrant workers, especially those not insured, to gain appropriate medical treatment and compensation.

25.2.2 Accident Statistics: Fatalities and Injuries

Comprehensive data on accidents is naturally difficult to find, for China is vast in area and population, but also, in common with most developing countries, such data are sensitive and the aggregation and transmission process of the statistical data is complex and distortion probably occurs. The following major sources of statistical data which have been made public on official Web sites may be consulted directly: State Administration of Work Safety Supervision (www.chinasafety.gov.cn), State Administration of Coal Mine Safety (www.chinasafety.gov.cn), and Ministry of Public Security (www.mp3.gov.cn). In contrast with national approaches in other countries, data related to musculoskeletal disorders or work-related psychological problems are not included.

Work Safety has received much attention in the past 5 years and has resulted in significant and continuing improvements. Nevertheless, the total number of the accidents is huge. In 2007, accidents of all types totaled more than 500,000, including over 100,000 fatalities. The following overview is based on published data (National Institute of Safety Science and Technology, 2004; State Administration of Work Safety, 2007; Li, 2008; Zhou, 2008):

1. In 2007, the total number of accidents fell and the number of severe accidents (that is those involving multiple fatalities) also fell. There were 506,376 accidents of all types, including 101,480 fatalities. This was a reduction of 19% and 10%, respectively, compared to the same period the previous year. The number of the severe accidents involving three to nine deaths and the number of resulting deaths decreased 10% and 9%, respectively, as compared to the same period the year before. The number of most severe accidents, those involving more than 10 deaths, dropped 10% and the resulting fatalities by 3%. The accidental death rate has fallen significantly since 2003; the number of people who died in 2007 was 37,913 fewer than in 2002, a drop of 53%.
2. The accidental death rate for every 100 million Yuan of GDP also dropped, from 1.33 in 2002 to 0.56 in 2006 and to 0.41 in 2007. Traffic safety improved too; the death rate for every 10,000 vehicles on the road fell from 13.7 in 2002 to 5.1 in 2007. The mortality rate in coal production per 1 million tons fell from 4.94 to 1.49 in this period.

25.3 Review of Academic Programs and Related Programs

In 2006, there were a total of 2311 ordinary colleges in China, comprising 720 universities and 1147 junior colleges. As many as 767 institutions offer postgraduate degrees—450 universities and 317 scientific research institutions (Ministry of Education, 2006). The number of students enrolled in higher education continues to increase. In 2006, the overall enrollment in all types of higher education was in excess of 25 million people, representing a matriculation rate into higher education of 22%. The study of ergonomics in China is fast developing and, while currently small in scale, is an emerging educational domain. The development of ergonomics studies in China started after the 1980s, and is normally found in departments of engineering and psychology. Seventy-two universities have ergonomics programs where the main courses offered include human factors engineering or ergonomics, engineering psychology, human–computer interaction, work safety, and epidemiology. Major universities in this domain include Tsinghua, Xi'an Jiaotong, Tianjin, and Zhejiang universities (Gaokao, 2007).

Within the schools of engineering, it is the departments of industrial engineering which have mainly been involved in the development of ergonomics curricula. Such is the case with the Department of Industrial Engineering at Tsinghua University in Beijing which was founded in 2001 (www.ie.tsinghua.edu.cn) and may be regarded as typical of advancing programs. The undergraduate curriculum includes courses in work study, human factors engineering and ergonomics, safety engineering, and product development and design. The curriculum for graduate students includes systematic engineering and designing, human computer interaction, advanced safety engineering, and work organization and ergonomics

and two English language taught courses, namely, ergonomics and work organization. After seven years of rapid development, there are at present a total of eight faculty members and about 50 graduate students in the program. An Institute of Human Factors and was founded in 2007 and the research directions include human–computer interaction and usability, biomechanics and anthropometry, virtual reality and simulation, and workplace design. Additionally, the institute has established collaborations with domestic and international enterprises and academic organizations, such as a work safety project in cooperation with Liberty Mutual's Research Institute for Safety. Ergonomics is also being developed within schools of psychology. A good example is the Institute of Psychology, CAS (www.psych.ac.cn). The chair of the institute, Professor Kan Zhang, is also the head of ergonomics study and the former chair of the China Ergonomics Society (CES). The institute's Laboratory of Cognition and Experimental Psychology has 17 researchers mainly engaged in research for applying cognitive psychology in the interaction between the humans, organization, and information. The Department of Psychology at Hangzhou University has established the National Key Laboratory on Industrial Psychology, which is the only state-level laboratory in psychology in China (www.psych.zju.edu.cn) and includes ergonomics courses. Finally, schools of public health have ongoing ergonomics activities illustrated by the School of Public Health at Peking University with seven departments including the Department of Occupational and Environmental Health Sciences (sph.bjmu.edu.cn), which was founded in 2000 and currently has nine professors and 25 graduate students.

25.4 Associations Relevant to Ergonomics

There are many ergonomics-related associations in China, but interaction and cooperation between them is quite limited because of their widely separated geographical locations and domains of specialization. However, reflecting the rapid growth of related domains, both in academia and industry, ergonomics-related associations in China are also developing rapidly. Some of the more important academic societies include:

The CES (www.cesbj.org) was founded in 1989, and the present chair is Professor Sheng Wang from School of Public Health at Peking University. Currently there are approximately 450 members from organizations such as universities, research institutes, and enterprises. CES has set up several specialized technical committees, which hold annual meetings while the main society holds a meeting every four years. The periodical of the society is the *China Ergonomics Journal*, which is issued four times a year. In 2009, the CES will sponsor the Congress of the International Ergonomics Association in Beijing.

In 2003, the China Work Safety and Health Association (COSHA, www.cosha.org.cn) was developed from the China Labor Protection Society of Science and Technology founded in 1983. The association was formed by the consolidation of elements of many organizations including the State Labor Bureau, the China Labor Union, the Ministries of Health, Coal Industry, Metallurgical Industry, Communications, Aviation Industry, Mechanical Industry, Weapon Industry, and of the Petroleum Industry. The Road Traffic Safety Association of China (www.rtsac.org) was established in 1994, and is administered by the Ministry of Public Security (2008). The association is mainly engaged in publicizing and popularizing traffic safety knowledge, developing traffic safety research, organizing conferences, and meetings on traffic safety. There are now more than 80 member organizations and more than 60 council member organizations including national ministries and commissions, traffic police departments, road traffic safety associations at provincial and municipal levels, as well as universities and research institutes. The association publishes

the magazine *Road Traffic Management* and publicizes the road traffic management laws, regulations, and policies. The China Chemical Safety Association (www.chemicalsafety.org.cn), originally known as The China Chemical Engineering Safety and Health Society of Technology, was renamed in 2005. It has 220 member organizations, mostly former state-owned large and medium chemical enterprises and some large-scale medicine manufacturing enterprises and is administrated by the state-owned Assets Supervision and Administration Commission of the State Council.

The China Association of Labor Protection Enterprise, established in March 1993, is a nonprofit organization composed voluntarily of entrepreneurs engaged in the safety- and health-related industries and work protection product manufacturing industry, as well as experts and scholars engaged in related research and testing, and academic organizations. The objective of the association is to provide services to enterprises as well as governmental departments and offices. The China Fire Protection Association, CFPA (www.china-fire.com), is registered and founded as an academic, professional, and nonprofit organization, being composed voluntarily of fire protection science and technology specialists and fire protection research and academic organization, and enterprises. The Usability Professionals' Association China DDF (UPA, www.upachina.org) was established in 2004, with the goal of providing China with a professional platform for the exchange of information and studies in product designing, testing, evaluation, and implementation. It has been growing rapidly because of the need for product design in China's markets.

25.5 Review of Nonacademic Training Opportunities

At present, nonacademic training in ergonomics is mainly found in the field of industrial safety and is a component of the two certificates of qualification, those for safety engineers and safety assessment engineers. The qualification for safety engineer (www.ccsea.org.cn) is a professional qualification admittance test, organized by the Ministry of Personnel and the State Administration of Work Safety, which includes four subjects, production safety law and related laws, production safety management, production safety technology, and case study on accidents. Successful participants obtain the Registered Safety Engineer Qualification Certificate of the People's Republic of China, which is effective and accepted anywhere in the country. The safety assessment engineer qualification test (www.ccsea.org.cn) is organized and implemented by the State Administration of Work Safety. The test includes two parts, basic knowledge and application of safety principles. Besides these two qualifying certificates, many enterprises have already developed training for international standards such as OHSAS18001, ISO9000, and ISO14000 in accordance with the requirements for international products and international business partners. Finally, Office Ergonomics has also gradually drawn attention and many enterprises have already started to give training to their employees.

25.6 Final Thoughts on Next 3–10 Years

Looking 3–10 years into the future, we believe the development of ergonomics in China will lead to remarkable changes in several aspects as more institutions of higher education start related curricula and specialties, and international collaborations increase.

Enterprise-based ergonomics will also show developments by paying more attention to improving productivity and safety through the application of ergonomics, and the insurance and social welfare systems will improve considerably.

Chinese universities are changing rapidly to better reflect the rapid growth of China's economy. The majority of Chinese universities are beginning to examine models of other famous and effective institutions from the rest of the world, as a means for establishing new courses and new programs. Therefore, while many domestic and foreign universities already have ergonomics courses or programs, more and more Chinese universities will gradually add ergonomics courses or programs. This trend will also lead to the development of domestic and international academic activities, publications, conferences and meetings, as well as professional training. At present, Chinese participation in international interactions mainly takes place in large cities such as Beijing and Shanghai. As other regions develop, there will be more chances for Chinese people to learn of, and apply, ergonomics lessons from other countries. China's demand, as well as supply, of international books, journals, and other academic publications will grow rapidly. This will lead to an opportunity for international ergonomists to interact with Chinese ergonomists and professionals in related fields in China.

Many Chinese enterprises are transforming gradually from processes leading to the hiring of cheap labor to make and export low-quality products, to processes providing high value added products and services for both domestic and international markets. These enterprises are discovering that ergonomics is necessary for the success of such transformation and increasingly they seek to work with ergonomists to improve productivity, safety, and customer satisfaction. The insurance and social welfare systems in the larger Chinese cities and in the coastal provinces are more advanced compared with that in other areas, putting much attention on supporting and helping workers. As a result of the need for economic development, these areas will continue to improve their insurance and the social welfare systems. In spite of these positive trends, there are still some potential problems including the general public's lack of awareness, the very large disparities in living standards, and the healthcare and insurance systems. Finally, China like many other developing countries chooses to focus on reducing accidents which result in fatalities, rather than the occupational injuries and disorders not resulting in immediate death. We believe that this is largely due to the lack of visibility of the true value of the economic and social burden of occupational injuries which remains largely hidden in contrast with the public attention paid to fatalities—especially incidents involving multiple fatalities. We believe that as China's healthcare and insurance systems develop and become more inclusive of all workers, that the collection and study of injury data will create opportunities for ergonomics to contribute very significantly to the safety and health of the Chinese people.

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26

Growth of Ergonomics in India

Anindya K. Ganguli

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26.1 Pioneering Efforts

More than five decades ago, at about the same time that the European Productivity Agency (EPA) established a Human Factors Section (1955), Indian ergonomics is generally thought to have been born in the Physiology Department of the Presidency College, Calcutta, where extensive work was done on the energy metabolism of rickshaw pullers and the body surface area of the Indian adult population. These pioneering efforts in the academic domain were extended in the early 1960s to the Industrial Physiology division of the Central Labor Institute, Mumbai and the Work Physiology and Ergonomics division of the Central Mining Research Institute, Dhanbad, both affiliated to the Government of India. Thereafter, ergonomics has spread in sporadic bursts in the academic environment, defense, agriculture, and design sectors and in industry.

It has been said that ergonomics concerns work, and extensive work is done in the industrially developing countries. However, to make a real impact on the majority of the workforce, ergonomics must reach the unorganized sector, where hundreds of different occupations employ a significant section of the population (arguably more than 20% of the world's working population). Moreover, ergonomics solutions in such situations should be low cost and indigenous in order to improve the occupational health and safety of the workers, while also increasing productivity. It is only then that solutions are adopted quickly and effectively, especially in the low income unorganized sectors. These factors are very important in India, where 90% of the total workforce is unorganized.

26.1.1 Overview of the Development of Ergonomics

Ergonomics research in India over the past five decades has focused on the following main areas:

1. Physical work capacity, work stress of different occupations—both industrial and unorganized
2. Diverse anthropometry of the people of this region
3. Load carrying—mainly in the unorganized sector
4. Improvement of working conditions in adverse environments, including hot and humid environments
5. Certain aspects of agriculture (upon which most rural people still depend) including high profile areas like tea cultivation
6. Low-cost improvements for some traditional and unorganized sectors
7. Product design
8. Women at work
9. Electronics and information technology (IT) sectors

Ergonomics research, teaching, and practice were introduced in the above areas at different times through different institutions. A glance at some of these institutions and the type of ergonomics activities at each location gives a quick overview of the way ergonomics developed in India.

In the early 1960s, the Industrial Physiology division of the Central Labor Institute, Mumbai, under the Ministry of Labor, Government of India, evaluated the work-loads of different occupations such as steel workers, soap makers, forging, glass workers, mine rescue work, to name a few, and prescribed standard methods for categorizing the heaviness (extent of the physical demands) of these and other jobs. An acceptable work-load for Indian industrial workers was also defined, and in addition the anthropometry of the Indian population was studied in detail. Similar studies were initiated at about the same time at the Central Mining Research Station, Dhanbad.

The first teaching of ergonomics took place at the Department of Physiology, University of Calcutta around the year 1971, where a postgraduate science course in Work Physiology and Ergonomics was offered. Many of those who now lead ergonomics throughout India learnt the basics at this institution. In parallel, this laboratory undertook research in many hitherto unexplored areas, including physical work capacity, load carrying, shift work, anthropometry (including segmental weights and centers of gravity), and agricultural ergonomics where comprehensive studies of different aspects of rice cultivation, tea leaf plucking were conducted. In addition, ergonomics analysis of railway operations, including design of track maintenance and tools, driver cabins, and many other aspects were carried out.

The National Institute of Occupational Health, Ahmedabad, was established in 1966 under the Ministry of Health and Family Planning, Government of India, and from the second half of the 1970s its Occupational Physiology division did extensive research in thermal stress and comfort, agricultural ergonomics, and female workers. These were supplemented by regional centers throughout the country. The All-India Institute of Hygiene and Public Health, Kolkata, an institute aimed at developing a healthy human workforce by providing postgraduate teaching and training facilities, also carried out research in ergonomics from the second half of the 1970s, the focus being on load carrying and the occupational stress of pulling a hand-pulled rickshaw.

Ergonomics was introduced as part of the industrial design curriculum at the Industrial Design Centre of the Indian Institute of Technology Bombay (IITB), in the year 1979 at the postgraduate level, and later at the Indian Institutes of Technology

Delhi, Guwahati, and Kanpur, at the Indian Institute of Science Bangalore, and also at the National Institute of Design (NID) at Ahmedabad, where they ran postgraduate and graduate programs. All these centers contributed to the integration of ergonomics with product and interface design in their respective design curricula in association with PhD programs. While the Industrial Design Centre catered to graduate engineers, the NID at Ahmedabad introduced ergonomics into the design curriculum of nonengineer designers at the graduate level. The development of a national anthropometric database and publication in 1998 of the book *Indian Anthropometric Dimensions for Ergonomic Design Practice* has been one of the major achievements of this center. From about 1985, ergonomics at the National Institute of Industrial Engineering (NITIE) in Mumbai centered on engineering aspects, especially those relating to industrial engineering. Aided by the government, NITIE has established a Center of Excellence in Ergonomics and Human Factor Engineering (CEEHFE) as part of the Indian Government's Technology Mission-2020 through Technology Information Forecasting and Assessment Council (TIFAC)—mission Relevance and Excellence in Achieving New Heights (REACH) in the educational system. NITIE has one of the finest ergonomics laboratories in the country, and a Diploma in Ergonomics (DErg) program was started in April 2006.

Ergonomics has always been a part of defense research, and India has been no exception in this regard. In 1962, a full-fledged laboratory was established, the main areas being physiological responses under extreme environments (including high altitude), and the ergonomics assessment of workstations and the human–machine interface. During the early years, the Defense Institute of Physiology and Allied Sciences (DIPAS) contributed extensively in major areas of immediate application to defense operations, including the nutrition of soldiers, load carriage, and distribution in infantry soldiers, and thermal comfort. While continuing with these issues related to immediate operational needs, research studies were carried out on performance in extreme environments, development of a protective mechanism against noise-induced hearing loss, and the evaluation of thermal protective clothing. Today, DIPAS is a leading laboratory in physiology and biomedical research in the country with the primary mandate of promoting human performance in the extreme environments of defense operations.

The earliest reports of enterprise-level ergonomics in India came from the Hindusthan Lever works (the Indian arm of Unilever) and Tata Steel. The public-sector Bharat Heavy Electricals Ltd. (BHEL), Tiruchirapalli, was the first in Indian industry to introduce an in-house Ergonomics unit in 1983, as part of its comprehensive Occupational Health Service, which is itself a national pioneer in terms of implementation of ILO recommendation 112. At BHEL, ergonomics research was primarily concerned with the problems on the shop-floor. Some of the major areas of concern were energy balance of manual material handlers, ergonomics evaluation of nonrespiratory personal protective devices, improvement of working conditions during welding and gouging operations inside boiler drums, and the development of a job analysis format incorporating occupational health and safety components. Other public sector undertakings, notably the Steel Authority of India, have followed the lead and are replicating the BHEL model.

26.1.2 Formation of the Indian Ergonomics Society

In January 1979, the Presidential Address of the Section of Physiology at the 66th session of the Indian Science Congress, held at Hyderabad, spoke of "Ergonomics, Science and Technology of Man at Work: its Role in our National Development." For the first time, the importance of the study of ergonomics and the significant role it can play in national

development was emphasized at a major conference. In 1983, a consensus was reached to form an Indian Society of Ergonomics. A proposal for its formation was discussed in Ahmedabad, in October 1985, and the Society was formally established in January 1987, again, at Ahmedabad.

Under the auspices of this society, national and international conferences are organized at different locations across the country. Initially, it was proposed to have a scientific meeting annually. Every second meeting would be a national conference, and every fourth one an international conference. Of late, the demand from different host institutions has been so strident that a national ergonomics conference with international participation has become an annual event. There has been a strong presence of the International Ergonomics Association (IEA) at most of these meetings, and the organization of pre- and postconference workshops on ergonomics methods, checkpoints and the like has helped to boost the popularity of these events.

26.1.3 Islands of Excellence

At the inauguration of one such international ergonomics conference in 2001, it was emphasized that one of the notable features of the world we live in today is the huge difference between what is known and what is put into practice; the difference between the "islands of excellence and the oceans of deprivation," the difference between the use of leading edge technologies and conventional ones, the difference between organized sectors of the economy which have achieved high productivity and quality, and unorganized sectors which are striving for emancipation from their economic backwardness. In spite of "islands of excellence" in the form of a large number of academic, research, and industrial institutions practicing, teaching, researching, and applying ergonomics, problems still exist, particularly those relating to the external recognition of the discipline of ergonomics and feelings of ineffectiveness locally.

The correct time for effective implementation of ergonomics is early in the design, development, or construction stage. In this context, "early" means the conceptual stage. Even by the time the design has been frozen on the drawing board, it is usually too late for anything except a token effort. Moreover, when modification is attempted in an existing system or set-up through small changes, reorganization, and other "patch-work" solutions, the cost of such modifications is not only inordinately high, but the results are also relatively disappointing. Often a partial solution brings out or accentuates other (latent) incompatibilities. This leads to a sort of "boomerang effect" in ergonomics, with ergonomics changes often producing little or no improvement. This has negative consequences for the credibility of ergonomics as a viable solution provider for work problems, especially in a developing economy with low purchasing power and high availability of skilled labor.

26.1.4 The Promise of the Future

Encouraging signs are evident in the proliferation of ergonomics in the areas of agricultural engineering and home science (family resource management). The increasing funding of ergonomics research and the exponential output of results in the form of scientific papers from these areas auger well for the benefit of ergonomics research and practices percolating to where a very large majority of the population is occupationally engaged.

The future holds promise. Growth in high technology sectors such as aerospace, automobiles, consumer electronics, and IT poses problems that have viable and demonstrable ergonomics solutions. Inclusion of ergonomics professionals in the different committees of the Bureau of Indian Standards is a positive step in this direction. Environmental and safety concerns are becoming major drivers of ergonomics programmes. Of particular importance in this regard is the new Occupational Safety and Health Assessment Series (OHSAS 18001:2007) standard which calls for substantial ergonomics considerations.

27

Development of Ergonomics in Iran

Majid Motamedzade

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27.1 Introduction

Ergonomics is as old as human endeavor. The quest for a natural "fit" between humans and their tools is a key factor in the development of the human species. As a formal applied science (with a much longer history in industrialized countries), ergonomics began in Iran in the early 1970s as a university course. In 1971, Nader Kavoosi, an Iranian pioneer in ergonomics, translated the Grandjean classic into Farsi (Persian), and this event marks perhaps the starting point of the introduction of ergonomics into Iranian academe, and later into the industrial setting.

During the postwar period in Iran, a second wave of ergonomics development swept academic and industrial fields. Accordingly in 1992, an ergonomics conference was held in Tehran by the Iranian Ministry of Defense (Defense Industries Organization, Occupational Health and Safety Management) in cooperation with academics. The next year, Professor Houshang Shahnavaz, who left Iran in 1980 to work at Lulea University of Technology, Sweden, restarted his efforts of large-scale training in Iran, to foster ergonomics awareness generally, and to introduce ergonomics more widely in both universities and industries. Since then, ergonomics education in Iran has been offered within several professional programs.

27.2 Formation of the Iranian Ergonomics Society

From this background, and in order to prepare the way for the formation of the Iranian Ergonomics Society (IES), an ergonomics workshop for the Iranian university lecturers was held in May 2000 in Tehran. In the last session of this one week workshop, a panel discussion was organized and the idea of founding an ergonomics society in Iran was proposed by the organizers. It was unanimously agreed to constitute this professional body for the field, and participants made two historic decisions:

1. To elect a group from the participants to prepare for the foundation of the IES
2. To select a day from the Iranian calendar as "Ergonomics Day," to be celebrated each year in Iran

Following a year of hard work and the secured acceptance by the Commission for Scientific Societies of the Iranian Ministry of Health (February 2001), the IES was born. The first election of the board members was conducted in May 2001. More than 50 delegates attended and in accordance with the IES constitution, 28 of them were eligible to vote. Today, the IES is officially acknowledged to be the professional body of ergonomics in Iran.

27.2.1 Networking

Over the past decades, several Iranian world-class specialists, including ergonomists, have immigrated to Western countries. Today, there are Iranian ergonomists working in the United States, in Canada, and in several European countries. Professor Houshang Shahnavaz, the father of modern ergonomics in Iran, is one such recognized world-class Iranian ergonomist. Certainly, without his commitment to ergonomics development in Iran, the foundation of the IES and the subsequent wave of ergonomics development in Iran would have been impossible. Forming both local and international networks, and involving all Iranian and many foreign ergonomists in realizing the mission of our new society has been one of the critical strategies of the IES and is stressed in the IES constitution. The backbone of this network is well formed and several of the Iranian ergonomists working in the West are involved in IES activities. The IES was formally accepted as a federated society of International Ergonomics Association (IEA) in 2003 and this event further consolidated our networking strategies. In the near future, using our local and international potential, the IES is expected to meet the scientific and practical ergonomics needs of Iran.

27.2.2 IES Membership Policy

Anyone interested in ergonomics can become a member of the IES. About 30% of IES members work at universities and similar educational institutions. Around 40% work in industries, the rest being engaged in governmental and private institutions. According to the IES constitution, important decisions can only be made at a general assembly, which takes place once a year during the society's annual spring meeting. Membership categories of the IES are as follows.

27.2.2.1 Full Membership

All faculty members of medical, technical and engineering, humanities, and art schools, and individuals holding at least a master's degree in one of these disciplines may become a full member of the society.

27.2.2.2 Associate Membership

Individuals holding at least a bachelor's degree in a relevant cognate field, and having passed at least two credit units in ergonomics, or those having acquired a credible diploma in the fundaments of ergonomics may apply for associate membership.

27.2.2.3 Student Membership

All students studying one of the above-mentioned majors, and who have passed ergonomics course(s) are admitted as student members.

27.2.2.4 Corporate Membership

Any organization or institute with scientific research activities related to ergonomics can subscribe as a corporate member.

27.2.2.5 Honorary Membership

Iranian or international scientific, cultural or social figures who are either well known or have contributed remarkably to the society in achieving its goals would be accepted as honorary members.

The current number of IES members is around 200. The IES office, via its secretary, handles the management of daily tasks. The president and other IES board members are elected for three years. The membership policy of the IES is strict regarding the qualifications of its members to ensure that it remains a scientific society whose members are both highly qualified and active in the field of ergonomics.

27.2.3 IES Goals and Activities

According to the IES constitution, the main goals of the society are:

1. To promote and maintain the well-being and satisfaction of individuals, both in communities and workplaces
2. To improve the productivity of human resources and organizations
3. To assure application of ergonomics principles in technology transfer based on local needs
4. To assure the development and expansion of knowledge of ergonomics and human factors engineering
5. To conduct research and innovation in ergonomics
6. To promote communication with international organizations

Among short- and long-term activities that IES has decided to pursue are the following:

- Create ergonomics awareness in Iran and encourage eligible people to join the society
- Develop a reference library at IES
- Regularly publish in the IES ergonomics journal (in Persian)
- Publish regularly the IES newsletter
- Create an e-group within the IES membership
- Cooperate with Iranian industries
- Organize national/international ergonomics conferences
- Develop local and international networking
- Design a master of science degree program in ergonomics at some Iranian universities
- Develop local ergonomics databases

The society celebrated its first "Ergonomics Day" on September 8, 2001 at the Iran Khodro Car Company. Over 400 guests participated in the associated seminar. The first issue of IES newsletter *Ergonomics Message* (24 pages) was distributed at the seminar. This newsletter has since been published regularly. A major initiative of the IES was the organization of a national conference in Tehran from October 29–30, 2002. The keynote speakers at this conference were Professor Houshang Shahnavaz, Director of CEDC from Lulea University of Technology (Sweden), Dr. Najm Meshkati from the University of Southern California (USA), and Dr. Jalali Naieni from the Iran University of Science and Technology. Over 850 delegates attended and more than 60 papers were presented.

Recently, an ergonomics e-group was established from within IES membership. The mission of this e-group is the "Promotion of Ergonomics knowledge and fluency in telecommunication for members all over the world." As is the case with other e-groups, such an accessible forum provides an outstanding opportunity for the delivery of ergonomics issues among the Iranian community. In autumn 2003, the first issue of the IES journal (*Journal of Ergonomics*) was published. This is the first scientific and technical Persian ergonomics journal in Iran.

27.3 Ergonomics Perspective in the Middle East

In the Middle East region, as in many other developing regions, ergonomics is in its infancy and great efforts are needed to introduce and convince people involved in decision making about the potential benefits of ergonomics implementing low-cost/no-cost solutions. It is necessary to provide educational services in the field of ergonomics, and help in the development of an ergonomics culture in this region. Introducing ergonomics to industries, and training employees and management in ergonomics "know-how" and practice is another basic part of the ergonomics perspective. The IEA and regional ergonomics societies could support the transfer of ergonomics knowledge to this region by organizing national and international conferences, seminars, workshops, and

publications. Recently the IEA, along with local ergonomists from across the Middle East, started moving toward forming a regional ergonomics society in the Middle East named the Arabian Ergonomics Society.

27.4 Conclusions

The goal of the IES is to contribute to the dissemination of ergonomics not only among its members, but also to create ergonomics awareness among as many people as possible. Introducing ergonomics to industries in Iran, and training employees and management in ergonomics know-how and practice is another main focus of the IES. The society provides educational services in the field of ergonomics, and helps in fostering the development of an ergonomics culture within the Iranian community. Although most of the interest in ergonomics in Iran has been in the academic fields with substantial research being conducted and published nationally and/or internationally, over the last decade there has been a significant increase in awareness of the benefits of ergonomics from within Iranian industries and in both the public and private sectors. Iran, as is the case with other industrially developing countries, needs ergonomics input. The potential for growth in ergonomics research and application is enormous, making it a challenging and rewarding field to work in.

28

Ergonomics in Russia

Alexey N. Anokhin

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28.1 Brief History and Current State of Ergonomics in Russia

The evolution of ergonomics in Russia started in the 1920s. The main areas of work in this period were industrial design, physiology, biomechanics, and "psycho-technology," and the main contribution to the industrial design was made by Russian avant-garde artists who proposed the idea of "industrial art" (Vlasov, 1995). They were inspired by the idea of building a new society where humans deal with modernity under comfortable work conditions. They asserted that artists must be involved in the design of industrial machines, workplaces, and interiors. "Constructivism" and "proletarian art" advanced in fine art and architecture during the early 1920s were the prime art styles influencing the industrial design. Early in the 1920s, the famous artist–constructivist V. Tatlin established the research and design institute for "material culture" in Petrograd (now St. Petersburg). This institute designed handy and highly artistic everyday goods such as chairs, beds, and cooking utensils. Another principal figure in Russian constructivism was A. Rodchenko who made contributions to graphical design and the design of multifunctional objects.

In 1918, the Institute for the Study of Brain and Psychical Activity had been established under leadership of the famous Russian physiologist V. Bekhterev, and the Department of Occupational Psychology was created. In 1920, Bekhterev and Myasischev proposed the establishment of a new discipline of science studying labor—ergology or ergonology. In the 1920s, V. Ukhtomsky began research activity in the area of occupational physiology. He established a laboratory for studying work in industrial plants in Petrograd. At the same time, the Central Institute for Labor was established. An essential contribution to the development of ergonomics in Russia during this period was made by N. Bernstein who popularized the basics of biomechanics (Munipov and Zinchenko, 2001).

In the 1930s, psycho-technology, a new discipline directed at the analysis and improvement of occupational activity, was formed in the USSR. Intensive research was undertaken

in the area of aviation ergonomics with studies undertaken on airplane cockpits focusing on handles, instrument panels, pilot seating, and the navigator's workplace. Many large-scale plants at that time established psychophysiological laboratories which conducted studies on the improvement of human work with machines and production lines. The Psychotechnology Society and *Soviet Psychotechnology* journal were established. However, in the middle of 1930s, all activity in the field of psychotechnology was stopped as the result of political decrees and repressions in the USSR.

An attempt to restore study in the area of occupational psychology in the USSR occurred at the end of 1950s. At this time two terms, engineering psychology and ergonomics, were brought into use. As in other developed countries, the defense establishment was the main resource of work in this area, in the applied fields of aviation, space, and defense technology. Research laboratories in engineering psychology were established in Leningrad State University in 1959 (under the leadership of B. F. Lomov), and in the Institute of Automatic Equipment in 1961 (under the leadership of V. P. Zinchenko). Great contributions to the development of the discipline at that time were made by renowned Russian psychologists B. G. Ananyev, A. N. Leontyev, P. Ya. Galperin, and others.

At the beginning of the 1960s, work in the area of equipment and environmental design was intensified. In Moscow, the Research Institute of Technical Aesthetics (industrial design) (VNIITE) comprising the Department of Ergonomics was established. Within a few years, VNIITE had founded 10 regional branches in the biggest cities of the USSR. The institute carried out ergonomics projects in the civil sector, promoting and popularizing ergonomics and industrial design. The VNIITE researchers greatly contributed to the application of ergonomics principles in the design process. In the 1960s, Professor V. M. Munipov and colleagues published the first textbooks, guidance, and a journal on ergonomics.

The 1970s and 1980s saw accelerated progress both in the civil and defense sectors. The team, under leadership of Professor P. Ya. Shlaen, developed a series of ergonomics standards for defense equipment design; they also established the Ergonomics Research and Development Centre which still remains one of the leading ergonomics organizations in Russia. Broad research and development work toward a theory of human–machine systems (HMS) (in the navy, space, and aviation) was done by Professor A. I. Gubinsky and his colleague Professor V. G. Evgrafov. Gubinsky systematized the main terms in ergonomics (such as operator, error, reliability, and efficiency) and proposed a theory for integrated analysis of HMS, including analysis and assessment of HMS and operator reliability and efficiency (Gubinsky, 1982). Early in the 1970s, he created the generalized structure method which provides a basis for functional–structural task analysis and the calculation of error probability and operator response time. This method is still used for analysis of operator reliability.

In nuclear power, most efforts were spent in design of control rooms (Anokhin and Ostreikovsky, 2001). Designers of the first large-scale control rooms for nuclear power plants (NPP) used active mimic diagrams which integrate representation of equipment status, main process parameters, and alarms. These diagrams were realized using big luminescent panels or conventional lamps and instruments (Figure 28.1). Today a full-scale mock-up enabling experimental ergonomics assessment of new NPP control rooms design is used (Marshall et al., 2007) (see Figure 28.2).

While the positive influence of ergonomics in the defense and industrial sectors was evident, there was no significant progress in the area of consumer goods. In spite of the fact that such institutes as VNIITE and others were designing advanced and carefully elaborated samples (irons, kettles, furniture), the industry did not implement these ideas in serial production because of the absence of materials and technology, low corporate culture, and the absence of serious competition between different manufacturers in the USSR.

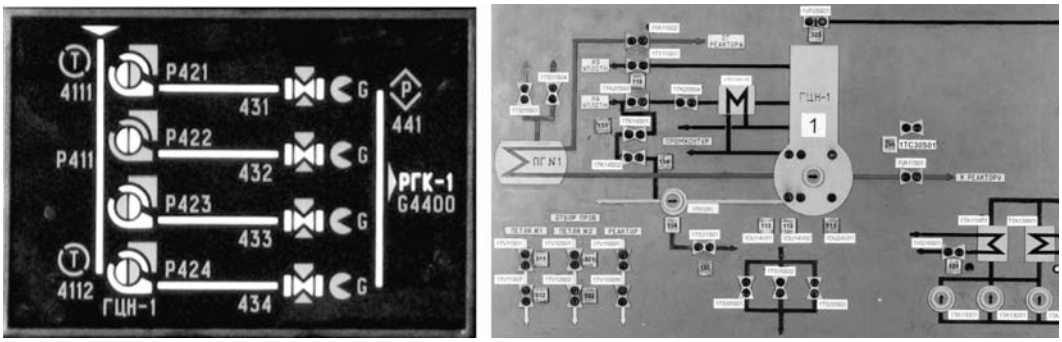

FIGURE 28.1
Active luminescent panels (left) and conventional mimic panel (right) (early 1970s).

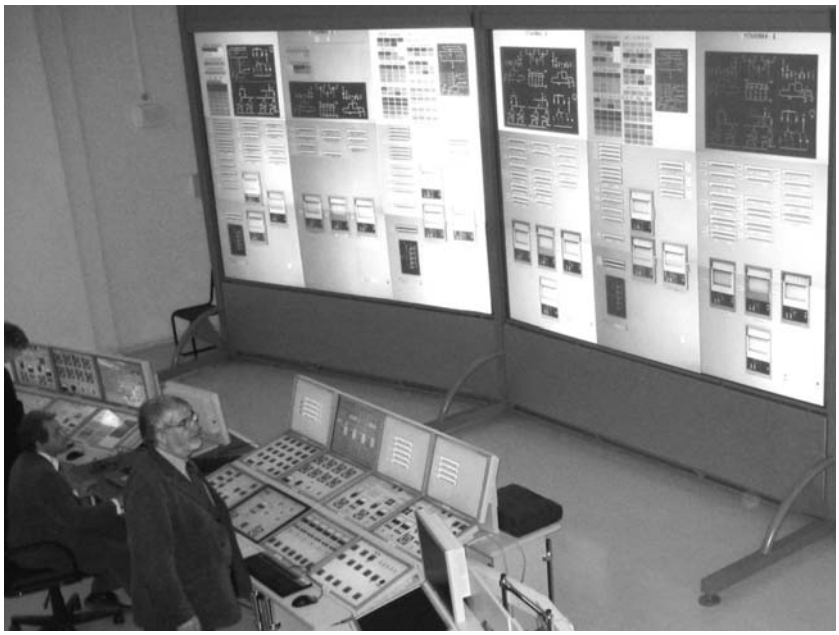

FIGURE 28.2
Mock-up tool for the assessment and validation of control room design proposals.

The economic recession of the 1980s and 1990s aggravated the situation. Most research and applied work in the field of ergonomics was stopped because of lack of money and setbacks in production. Some professional ergonomists changed their area of activity, with the exception of human–computer user interface designers. At the start of this century, the economic situation in Russia began to change. As a consequence, activity in different fields of ergonomics was intensified. Step by step many industrial plants replaced production equipment and technology, implementing new human-oriented approaches to the design and manufacture of goods. The conversion of military technologies enabled the production of goods with advanced ergonomic characteristics. The institutes and organizations for ergonomics began to intensify their activity, among them the Center for Ergonomics

Research and Development (Ergocentre), the Russian Institute for Protection and Economics of Labor, VNIITE, the Laboratory for Ergonomics Research and Development in Nuclear Power (ErgoLab), and the Mil Moscow Helicopter plant.

28.2 Russian Ergonomics Society

The Russian society of ergonomists known as the Inter-Regional Ergonomics Association (IREA) originated from the Soviet Ergonomics Association (SEA) established in 1986. The founder and first president of SEA was Professor A. I. Gubinsky. More than 100 practitioners and researchers in ergonomics from all Soviet Republics (now independent states) were members of SEA. The SEA hosted annual all-union conferences involving design, evaluation, and optimization of system operation, interregional workshops on ergonomics and efficiency of human–machine systems, and symposia on efficiency, quality, and reliability of human–machine systems. SEA became a federated society registered with the International Ergonomics Association (IEA). In 1993, SEA organized the first international conference "Ergonomics in Russia, Commonwealth of Independent States (CIS)," which was a once-off activity.

The IREA was established in August 1995 as an assignee of the SEA. The first president of IREA was Professor P. Ya. Shlaen. IREA is a nonprofit (noncommercial) public organization targeted at the facilitation of communication and collaboration between all specialists in ergonomics working in different regions of Russia. IREA activities include the following principal areas:

- Promote the development of ergonomics in Russia, cooperating with government bodies and organizations
- Support and review the research activities and dissertations in ergonomics
- Disseminate and share good experiences and standards in ergonomics
- Realization of any projects involving ergonomics
- Arrange conferences and scientific events and facilitate communication between Russian ergonomists (Web site, journal)
- Popularize ergonomics in the population at large, particularly among the decision makers in Russia
- Support education, training, and certification activities in ergonomics
- Promote cooperation with international bodies (IEA, FEE) and national ergonomics societies of other countries

The IREA consists of regional branches. Until now, the IREA branches are registered in six central regions of Russia—Moscow, Petersburg, Tver, Kaluga, Ivanovo, and Yaroslavl. Each branch has a head (chair) and its own suitable structure. There are currently about 200 ergonomists who are members of the IREA. Day-to-day activity is coordinated by an executive committee (EC) consisting of five officers under leadership of the IREA president (currently Professor V. M. Lvov). Most decisions are made by IREA Council (Presidium) which comprises all EC officers and all heads of regional branches. The principal decisions are made through voting which is conducted using e-mail. In 2001, IREA

instituted a medal for service in human factors research. In the same year, IREA founded the academy of problems associated with human factors. Annually IREA presents awards to leading ergonomists. IREA is a federated society of the IEA and Federation of European Ergonomics Societies (FEES). IREA activity is consistent with the policy and strategic plan of these organizations.

28.2.1 Education in Ergonomics

Higher education in the USSR and Russia is realized in accordance with core specialties (university programs). Before 2005, psychology was the only higher education program concerned with the field of human factors. Within this program, there is specialization in "occupational and engineering psychology." The Moscow and Leningrad (St. Petersburg) state universities implemented this program in the mid-1960s. From 1985 to 1989, the Leningrad Electro-technical Institute offered a postgraduate program in ergonomics. Since 2005, a new course, intended for training of professionals in ergonomics, was established in Russia. Graduates from this course receive a degree of "Engineer." The five year program involves a four and a half years course of theoretical study and a final six months project in ergonomics (usually in association with an industrial company). The results of this project are presented to an examination board which makes the decision regarding professional qualification. The theoretical course consists of lectures, seminars, and laboratory exercises in the following main disciplines (Educational Standard, 2005): psychology and pedagogy; sociology; philosophy; economics; mathematics (linear algebra, analytic geometry, mathematical analysis, theory of probability, and mathematical statistics); informatics; physics; chemistry; ecology; basics of human anatomy; physiology and biophysics plus ergonomics principles; basics of biochemistry; basics of physiology; hygiene and occupational psychology; anthropometry and biomechanics in ergonomics; quality management, certification, and standardization; safety and well-being; system analysis and modeling the human–machine system; theory of control systems; materials and technology; measurement of technical and medicobiologic values, protection of intellectual property and patenting; ergonomics for industrial and engineering systems design; ergonomics for display systems and human–machine interaction design; ergonomics assessment of engineering and manufacturing systems and consumer goods; habitability of workplace; occupational selection and training of operators; consumer goods design; ergonomics and marketing; and ergonomics for sociotechnical systems. In 2007, three Russian universities offered higher education programs in ergonomics: Moscow State Aviation Technological University, St.Petersburg; State Electro-Technical University; and the Institute for Ergonomics and Socio-Economic Technologies (Tver city).

28.2.2 Conferences, Journal, and Web site

Every 2 years, the IREA hosts an international conference "Psychology and Ergonomics: Unity of Theory and Practice" which takes place in Tver city. The fifth conference was held in August 2007. The same year, the third international conference on human factors in aviation and space took place under the patronage of several aviation institutions. IREA is the principal founder and publisher of the journal *Human Factors: Problems of Psychology and Ergonomics* which has been published since 1999. It addresses psychologists, ergonomists, and a wide range of practitioners. The journal publishes papers and information concentrating on the results obtained from scientific and applied works

in ergonomics, engineering, occupational, and social psychology areas. In 2006, IREA launched its official Web site which is available at www.ergo-org.ru. It provides information about current IREA activity in both Russian and English languages.

28.3 Conclusion

The slogans of "Good ergonomics—good economics," "Diversity in ergonomics," and "Ergonomic is a style of life" all emphasize that a human-oriented approach can be demonstrated everywhere—comfortable workplaces, handy control boards, and handles in cars, understandable and readable signs in metros and in the street, safe household appliances and kitchen instruments, entrances adapted for disabled persons, work environments auspicious for health to name but a few. Professional ergonomists in modern Russia take responsibility for all these issues.

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29

Experiences in Ergonomics Action Programs for Industry and Agriculture in Asia

Kazutaka Kogi

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29.1 Introduction

Ergonomics action programs are gaining impetus in Asia for products and facilities design and for improving industrial and agricultural workplaces. These programs reflect the growing awareness of the fact that the reduction of ergonomics-related risks at work is possible despite many constraints when workplace people are directly involved in preventing occupational accidents and many work-related diseases (Kogi, 1995, 1998, 2006; Kawakami et al., 1998; ILO 2001; Zalk, 2001).

A new trend in applying ergonomics in both industrially developing countries and developed countries is the use of participatory action-oriented programs. These programs have led to significant health-related changes in small- and medium-sized enterprises and in agriculture (Vink et al., 1995; ILO 1996; Hiba, 1998; Kawakami and Kogi, 2001; Kogi et al., 2003; Yoshikawa et al., 2006; Kogi, 2008). Keen attention is increasingly being paid to group work tools for applying practical ergonomics measures (Kawakami and Kogi, 2005; Kogi, 2008). Recent experiences in participatory action-oriented work improvement programs undertaken within our Asian intercountry network (www.win-asia.org) demonstrate the effectiveness of applying basic ergonomic principles for overcoming existing constraints. These programs commonly emphasize the role of "change groups" involving local people (Kawakami et al., 1999; Kawakami and Kogi, 2001; Kogi et al., 2005). It is useful to examine what types of ergonomics action programs are effective in improving ergonomics conditions and occupational safety and health in different work settings.

29.2 Typical Ergonomics Action Programs

Typical ergonomics action programs for improving work life within our Asian intercountry network apply similar methods based on participatory action-oriented training. These programs, coordinated among the partner institutions, have been applied to different work settings for training local people. They include the following programs:

- Work Improvement in Small Enterprises (WISE) courses for small- and medium-sized enterprises using the methodology developed by the International Labor Office
- Work Improvement in Neighborhood Development (WIND) programs for training farmers applying the methods originally developed in Vietnam
- Work Improvement for Safe Home (WISH) workshops for training home workers
- Work Improvement in Construction (WISCON) courses for construction workers
- Participation-Oriented Safety Improvement by Trade-union InitiatIVE (POSITIVE) activities by trade unions with the support of the Japan International Labor Foundation
- Participatory training in occupational safety and health management systems combined with training in work improvement in small enterprises (Khai and Kawakami, 2002; ILO 2004; Kawakami and Kogi, 2005; Kogi, 2006)

These programs are applied through the network partners in a number of countries in Asia including Bangladesh, China, Indonesia, Japan, Korea, Laos, Malaysia, Mongolia, Nepal, Pakistan, the Philippines, Thailand, and Vietnam. All the programs make use of participatory methods aimed at learning and applying practicable improvements in work life (Thurman et al., 1988; Kawakami et al., 1998 and 2004; Khai et al., 1998; Khai and Kawakami, 2002; Kogi, 2002; ILO 2004). Training is conducted usually through one to four day courses or workshops while WISE intensive courses for managers of small enterprises take one to two weeks. Typical short-term training programs using these methods are listed in Table 29.1. All these programs apply the group work steps with the help of action-oriented training tools. Many improvements have been reported by the participants of these various programs. Of special interest is the nature of participatory steps leading to concrete improvements and the way training tools enable people to act. The following three aspects of these change groups related to their successful outcomes

TABLE 29.1

Group Work Tools Used in the Reviewed Programs for Facilitating Local Low-Cost Actions

Group Work Tools	Purposes	Examples of Expected Results
Local good examples	Show participants locally applicable ideas	Learning low-cost improvements using local resources
Action checklists	Help participants look at available simple solutions	Quick identification of practicable solutions in diverse technical areas
Illustrated action guides	Examine different ideas so as to agree on priorities	Participatory action for immediate implementation helped by manuals
Trainers' manuals	Guide trainers about participatory steps taken	Support for local action with spreading effects

are examined: (a) build the initiative of local people who learn from local good practices; (b) focus on multiarea low-cost improvements; and (c) use action tools applying basic ergonomics principles.

29.2.1 Common Features of Effective Ergonomics Application Programs

29.2.1.1 Building on "Local Good Practice"

Basic participatory steps used by the reviewed programs are similar to building on local good practices (see Figure 29.1). Each program starts from learning local good practice by means of examples and organizing group work for identifying realistic actions. This process is done by change groups comprising local people who plan and undertake the necessary improvements. The role of the change groups is to go through the participatory steps to obtain concrete results.

These group work steps are based on the WISE methodology that applies basic principles suitable for building on existing practices. These principles are (a) build on local practice, (b) focus on achievements, (c) link working conditions with productivity enhancement, and (d) use learning-by-doing methods involving local people. This emphasis on local achievements, rather than on criticism, has actually led to numerous improvements. The participants are guided to identify existing good examples and then discuss if similar improvements can be proposed. The participants are thus encouraged to take initiative for improving their own workplace conditions despite the economic and technical difficulties met. For example, over 2000 improvements were planned during the WISE courses in the Philippines during 1994–1997. Of these proposed improvements, over 80% were implemented within the course period of up to two weeks. In the WIND workshops in Cantho Province in Vietnam, over 90,000 improvements were achieved in a one year period from 2002 to 2003. Case study results in the Philippines, Thailand, Japan, and Vietnam demonstrated that usually several improvements per enterprise were achieved, often incorporating materials handling, workstations, and physical environment together. These results suggest that the approach based on local good practice is suited to bridging gaps seen in many small-scale workplaces. We can confirm that participatory steps have real impacts when they (a) start from local achievements (rather than criticism alone), (b) look at opportunities (rather than difficulties met), and (c) proceed by self-help (rather than expert skills). The approach thus helps people overcome constraints on improving working life in small workplaces.

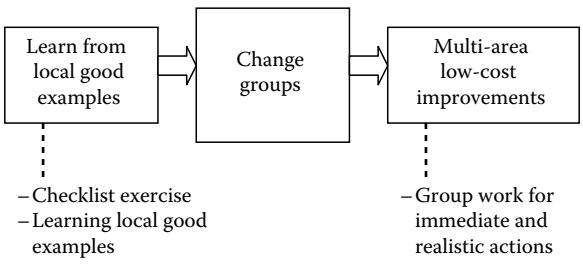


FIGURE 29.1
Basic participatory steps commonly taken to build on local good practices.

29.2.1.2 Focus on Multiarea Low-Cost Improvements

Participatory steps undertaken by the network partners are as a rule more successful when they focus on multiarea low-cost improvements. The generally low cost of the improvements undertaken is shown in Figure 29.2.

In the case of a WISE course in Thailand, 22 of 63 improvements effected by participating small enterprises were at zero cost, 23 were done at $20 or less, and 18 involved spending over $20. In the case of a WIND course in Vietnam, 28 of 88 improvements done by farmers were at zero cost, 37 required $10 or less, and 23 were effected by spending over $10. Usually, about one third could be done without any cost and many others were done at very low cost. A similar distribution of the improvement costs is seen in many other cases. It is important to note that there are many low-cost improvements in several of the technical areas covered. These results point to the merit of undertaking low-cost improvements simultaneously in different technical areas. The focus on low-cost improvements is thus considered essential for obtaining concrete results. All training tools used in fact play a vital role in encouraging people to undertake similar low-cost improvements in these different technical areas.

Thus the facilitating role of focusing on low-cost improvements may be summarized as follows: First, this focus helps aim at practicable results (rather than analytical procedures). Second, it facilitates the understanding of "how-to" information through the initiative of local people in the form of bottom-up (rather than top-down) process.

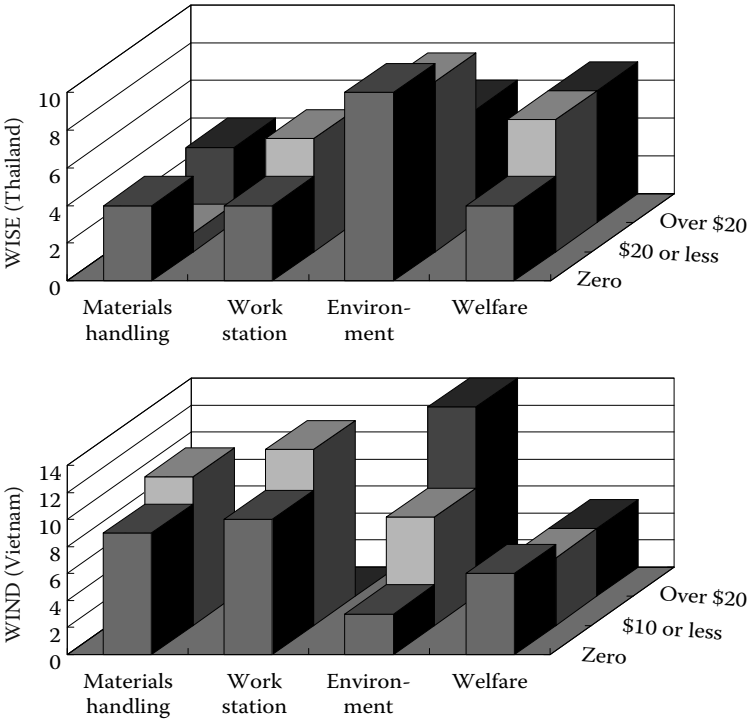
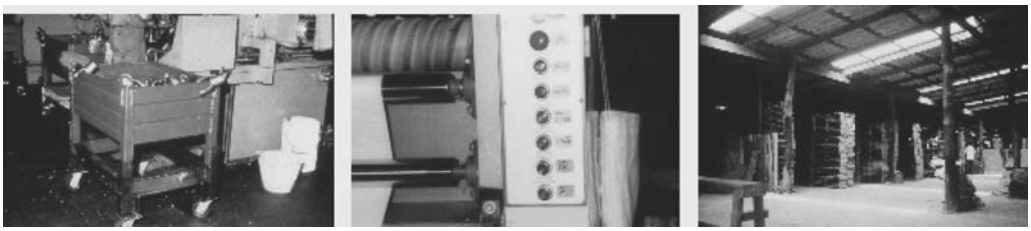


FIGURE 29.2
Distribution of costs of improvements by a WISE course and a WIND course.

(a)



(b)

(c)

(d)

(e)

FIGURE 29.3
Low-cost improvements achieved by participatory programs in different settings.

Finally, it helps make benefits visible (rather than emphasizing the complex nature of benefits to be obtained). Thus the focus on low-cost improvements can effectively stimulate the collaboration of local people. Examples of typical low-cost improvements achieved by the reviewed participatory programs in different settings are shown in Figure 29.3. These examples clearly demonstrate that low-cost improvements can be undertaken in various technical areas while reflecting the local situation at the initiative of local people.

29.2.1.3 Using Action Tools Applying Basic Ergonomics Principles

Our experiences in the above-mentioned participatory programs show that training tools used by the network partners are effective when they incorporate a set of basic ergonomics principles. This close link between action tools and basic ergonomics principles is striking. This has apparently resulted from the fact that despite many constraints, the group work tools incorporating a set of basic ergonomics rules are effective in encouraging people to make concrete changes. As a rule, these programs use photographs of local good examples, action checklists listing locally available improvements, and illustrated guides. In all the programs, these tools are considered essential in promoting the planning and implementation of practicable improvements. The purposes of the essential training tools are given in Table 29.1. The participatory tools used have two distinct features. First, basic ergonomics principles aimed at improving both working conditions and work efficiency are selected. There are many low-cost actions conducive to this aim. Second, each of the participatory tools incorporates multiple low-cost actions representing these selected basic principles. These tools have proven effective in implementing improvements in each local situation. This is the case for improving small industrial workplaces, construction sites, agricultural farms, and home workplaces.

Typically, "action checklists" incorporate about a dozen or more of such basic ergonomic principles as are shown in Table 29.2. These actions result in less manual materials

TABLE 29.2

Basic Ergonomics Principles Included in an Action Checklist for Participatory Steps

Major Technical Area	Basic Principles	Examples of Low-Cost Action Listed
Materials handling	Organized storage	Multishelves; home for each tool
	Use of wheels	Pushcarts; mobile racks
	Use of lifters	Mobile lifters; utilizing pallets
Workstation design	Easy reach	Bins in easy reach; side-stands
	Elbow height work	Foot platforms; adjustable chairs
	Use of fixtures	Jigs and clamps; hanging tools
	Easy-to-distinguish tasks	Labeling; color coding
Teamwork environment	Mixing daylight/lamps	Utilizing daylight; repositioning lamps
	Providing guards	Machine guards; interlocking
	Isolating hazard sources	Screening sources; safe wiring
	Self-paced work	Buffer stock; inserting breaks
	Refreshing facility	Sanitary facilities; resting corners

handling, more efficient work operations, and improved work environments. It is of interest to note that most action checklists used incorporate almost all of these (about a dozen) basic ergonomics principles. Such a set of basic ergonomics principles acts as a guide for designing information sheets, action checklists, and improvement manuals. In view of the observed merit of aiming at multiarea low-cost improvements, the inclusion of a selected number of basic ergonomics principles is always preferable. This allows each program to design such training tools in a consistent manner. The tools used in a serial manner are known to help participants understand the available options and their benefits.

29.3 Future Cooperation

The reported experiences in our Asian network for work improvement confirm the active role of participatory ergonomics in improving small workplaces. This is true for different working life settings including small industries, construction sites, agricultural farms, and home workplaces. It is demonstrated that participatory ergonomics is effective when building on local good practice. Group work tools supporting the participatory steps should focus on low-cost improvements available in each local situation. Each such tool should incorporate a number of basic ergonomics principles aimed at improving working conditions and productivity together. International cooperation is important in further developing ergonomics action-oriented programs in various work settings. In facilitating participatory steps, the use of group work tools such as action checklists incorporating selected basic ergonomics principles in their low-cost forms is recommended. The exchange of positive experiences through Web sites and databases is particularly useful. It is hoped that the enhanced international cooperation among developing regions will lead to effective ergonomics interventions to assist in bridging gaps in this field.

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Part VI

Insights and Reflections from Ergonomists around the Globe

30

Times Remembered: Reflections on the Postgraduate Program in Ergonomics at the University of Cape Town 1983–1999

Robert S. Bridger

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Life can only be understood backwards; but it must be lived forwards.

Soren Kierkegaard
Danish philosopher (1813–1855)

30.1 Introduction

The postgraduate program in ergonomics at the University of Cape Town (UCT) was the brainchild of Professor George Jaros, the then Hyman Goldberg Professor of Biomedical Engineering at the Medical School. The Department of Biomedical Engineering had a modular program, designed around a core of medical subjects, to enable graduate engineers to study for Masters and Doctoral degrees in the main areas of Biomedical Engineering. Professor Jaros decided to introduce new modules, such as ergonomics and medical informatics, so that the department could provide its engineering students with a wider range of options. Furthermore, the modular structure made it possible to develop a postgraduate Biomedical Sciences program, open to nonengineers, particularly those working in professions allied to medicine.

The Ergonomics Program ran from 1983 to 1999. It was established by Mr. H. M. ("Mike") Cooke, an ergonomist from Loughborough University in the United Kingdom. Mike was

a South African who had taken early retirement from Loughborough and was working short-term contracts in South Africa. Mike had made it clear to George that he would work at UCT for one year only and that a replacement ergonomics lecturer would have to be found. Thus, it was that I joined the department in a temporary capacity in March 1984 and soon after Mike began his well-earned retirement in Cape Town.

The establishment of an ergonomics program was a relatively simple matter because of the existing program strengths in anatomy and physiology. Two ergonomics modules were taught, *Introduction to Ergonomics* and *Information Ergonomics* (the former aimed loosely at biomedical engineers with a background in mechanical engineering and the latter for those with a background in electrical engineering and an interest in product design). Students passing both ergonomics modules and a one year Master's thesis in any area of ergonomics graduated as ergonomists.

The *Introduction to Ergonomics* module dealt largely with the issues relating to occupational health such as work-space and environment design and manual handling. *Information Ergonomics* dealt more with human error and interface design. Few engineers opted to take both modules and the emerging cadres of ergonomics students were those with a background in occupational health and safety and occupational medicine or psychology.

30.2 What Did We Achieve?

First and foremost, we trained ergonomists. Some of them are still working in that capacity in South Africa to this day. A brief summary of the academic track record serves to illustrate what it is possible to do in a developing country, given a supportive academic environment. I was very fortunate to receive support and encouragement from Professor Jaros (an electrical engineer and systems theorist) and from my PhD supervisor, Professor Maciej Henneberg (a physical anthropologist).

UCT Ergonomics Program 1983–1999

Postgraduate theses supervised	25
Articles in peer-reviewed journals	34
Articles in nonpeer reviewed journals	27
Papers in conference proceedings	29
Conference proceedings	2
Research reports	2
Books	2
Grants received	15
Short courses presented	20
Invited presentations	29

30.2.1 First Steps

Service teaching, as an end in itself, does not count for much in academia. However, as a way of getting to know people and to generate interest and enthusiasm for a relatively minor subject, it can have its advantages. Lectures on ergonomics to students at the UCT Physiotherapy and Engineering Schools helped to attract students to the subject. Some of them then went on to train as ergonomists. Lectures at the summer school and the

presentation of commercial seminars also attracted students. It became clear, very early on, that the poor working conditions in the country were already recognized and that many people were interested in doing something about it. The ergonomics training programs provided them with the skills they needed to tackle these problems, as in-house specialists or as ergonomics consultants.

Reasoning that ergonomics would never get support if it was not known, I began to write freelance articles on ergonomics for local publications, principally *Productivity SA*, published by the privately funded National Productivity Institute. In 1987, we launched a series of Office Ergonomics workshops throughout South Africa. These provided good publicity for our group and contacts with industry and commerce. This, in turn, led to further invitations to speak about ergonomics. I became notorious among academic colleagues after publishing an article on ergonomics for *Cosmopolitan* magazine.

30.2.2 Some Highlights

Interest in ergonomics in South Africa grew following the establishment of the Ergonomics Society of South Africa (ESSA) in 1984. UCT held the second annual ESSA conference in 1986 and, thanks to the efforts of Mike Cooke, the UCT Ergonomics Program achieved international recognition and appeared on the Ergonomics Society's list of approved courses.

Recognizing that many large corporations in South Africa were in the process of introducing office automation, we bid for funds to carry out a 3 year project on Office Automation in South Africa and received support from a consortium consisting of The Anglo American and de Beers Corporations, First National Bank, and The Southern Life Association. Christina Conway joined the team. A second major grant was received in 1989, from the then Department of Manpower and we began to investigate the prevalence of musculoskeletal ailments and work-space design practice in industry and commerce. Gillian Schierhout joined the team.

With the improvement in the political situation, the potential for international collaboration was recognized. In 1994, we obtained funding for Professor H. Shahnavaz of Lulea University, Sweden to visit our group in Cape Town and groups in Pretoria as well. This marked the start of several useful interchanges. I was impressed by the International Masters program that Professor Shahnavaz had established at Lulea and by the truly participatory approach they took when working with colleagues from IDCs. This was to become my first experience of a recurring theme—it is much easier for scientists in IDCs to obtain funding for visits than for research and laboratory equipment.

In 1995, the textbook *Introduction to Ergonomics* was published (Bridger, 1995). This book, which was subsequently translated into Chinese, is a good reflection of the core teaching of the UCT ergonomics program in its heyday.

The problem of obtaining funding to improve local research capacity is surely common in most IDCs. At the time, in 1994, I was not aware of this problem. However, in 1994, I spent three months at the Biodynamics Lab, Ohio State University with Professor Bill Marras to learn more about modern biomechanics research and to develop my ideas for research to find ways of reducing the burdens of subsistence farmers. I learnt a lot and we published a paper on spade redesign to show what can be done (Bridger et al., 1998). It became clear that we would need significant funding to develop decent research facilities in Cape Town.

In 1998, Pat Scott, Jack Charteris, and I organized the "Global Ergonomics" conference in Cape Town in collaboration with the International Ergonomics Association. The global financial crisis of the time had a major impact on many developing countries, preventing some IDC members from attending. The conference was not as "global" as I had hoped, for this reason, but overall attendance was good and we enjoyed a varied program.

30.2.3 Some Lowlights

In 1988, I represented the Ergonomics Society of Southern Africa at the 10th Congress of the International Ergonomics Association, Sydney, Australia, August 1–5, 1988 and presented ESSA's application for IEA membership. The application was rejected and, judging by the harsh words and rudeness of some of the IEA council members, I concluded that ESSA would be judged according to the politics of the country its members lived and worked in, and not for the work that it did.

From such negative beginnings, one might be forgiven for having positive expectations against the improving political background. It became clear, throughout the 1990s that the scope for developing research infrastructure by accessing international funding sources was limited. In 1995, the Deputy Dean of the Medical School warned us that with the improvement in SA politics, representatives of international development agencies were now "preying on the good will of local academics" to lure them into badly funded development work of limited academic value. Following contacts with international development agencies involved in agricultural research and with colleagues developing educational programs for the World Health Organization, it became clear that such agencies had their own priorities and that academics in IDCs were often perceived by them as little more than a source of inexpensive "local" expertise. I reflected that there always seemed to be funding to fly "experts" from ergonomically advanced areas to tell us what to do, but never for the equipment and infrastructure to enable us to do it ourselves. With the Deputy Dean's words ringing in my ears, I decided to stick to local funding sources in future.

Finally, in 1998, the global financial crisis had a major impact on South Africa, cutting the value of salaries and causing interest rates on home loans to peak at 25% per annum. I returned to the United Kingdom and the temporary post, which I had occupied for 15 years, was abolished in 1999 in a cost-cutting exercise.

30.3 Developing Ergonomics Programs in a Middle Income Country

There are many advantages to working as an academic ergonomist in a developing country. One of them is that you will very likely be the only ergonomist for hundreds if not thousands of miles (the distance between centers is particularly great in the countries of the southern hemisphere), and will be free to develop your own teaching and research programs according to local needs and interests. However, funding is always a challenge and you will need to take a flexible approach and work in areas for which there is funding. This may mean working in areas that are not your main focus of expertise or academic interest. This requirement for flexibility is fair and is reflected in the IEA Guidelines for Masters Programs in Ergonomics. These guidelines are specifically designed to produce ergonomists possessing a general knowledge of the subject, as well as strengths in specific areas—the kind of people who can adapt to the demands of the work environments in IDCs as they find them.

One of the disadvantages is the potential isolation, although this is mitigated nowadays by the Internet access, membership of ergonomics discussion groups on the web and electronic journal access. Sponsorship to attend international conferences is particularly important for academics from IDCs and is an area where support is always needed. Another disadvantage is that access to research and teaching equipment is likely to be limited. For basic ergonomics courses, a heat stress monitor, sound level meter and a light

meter are mandatory. These are relatively inexpensive. Some kind of video system for capturing and digitizing postural data is also useful as are a lumbar motion monitor and basic electromyography (EMG) system. In many IDCs, these will be expensive items due to local currency weaknesses and are an example of one of the key areas where external funding and international contacts really can play a useful role, as do the book donation schemes run by human factors and ergonomics society (HFES), IEA, and others.

In middle income countries, development means more than just improving working conditions. It also means developing the capacity to utilize and produce new technologies. This makes it difficult sometimes to locate ergonomics in an academic setting—the user-centered focus of ergonomics is cross-faculty (e.g., medical and engineering), which is why ergonomics was so well located in a Biomedical Engineering department. The balance between the medical and engineering themes can be difficult to achieve in a single course or textbook. See Bridger (1995) for an example of a text which attempts to achieve this balance, and Bridger (2008) for an updated version of the same thing.

30.4 Get It Right Next Time: The Benefits of Hindsight

The best funding we received, during the 16 years that the program ran, was obtained from local, rather than international, sources. This was partly due to the effects of sanctions against South Africa (from 1983 to the early 1990s) and partly because there were few sources of true research funding (rather than development aid) available from outside the country. A more inward-looking approach focussed on the needs of local organizations and the development of long-term working relationships with them would very likely have led to further project work and better funding. The disadvantage of carrying out this kind of applied research, that is focussed on the needs of organizations, is that projects only get done for organizations that have the resources to fund them (such as Banks or large Mining Corporations), which is not necessarily where the real ergonomically related problems lie. In the case of South Africa, much useful work might be done to ameliorate the daily burdens of subsistence farmers but accessing sufficient research funding will be a real challenge.

Traditionally, ergonomics in IDCs has focussed on health or occupational ergonomics and the improvement of working conditions (Chapanis, 1975). Although such work is highly appropriate to the needs of IDCs, one cannot fail to notice the rapid application of information and communications technology (ICT) in many IDCs and the scope for ergonomics research. On a recent visit to Chile, I was impressed by the large number of people, from all walks of life, who were using cell phones, automatic teller machines (ATMs), and other public ICT. Only toward the end of my time in South Africa, did we become interested in the cognitive ergonomics of ICT, thanks, largely, to the tenacity and determination of Claus Zimmerman with his work that demonstrated a link between ATM dialog design and the probability of card losses (Zimmerman and Bridger, 2000). Claus and colleagues have developed this work and have recently considered literacy (in own and other languages) and reading skill in relation to ICT design (e.g., Thatcher and Ndabeni, 2005). This is an area where more work might have been done earlier on. The last research proposal that I wrote at UCT was for a three year project to investigate ergonomic aspects of the productivity of ICT in the South African corporate sector, with the emphasis on a user-orientated approach, including adverse psychological outcomes caused by

computer-induced stress (productivity improvement being a major development goal for most IDCs). Unfortunately, this seemingly good proposal was overtaken by events and I had returned to the United Kingdom before it could be submitted.

30.5 Some Thoughts on the Promotion of Ergonomics in IDCs

Every year, many thousands of highly qualified people move from developing countries to developed countries to work, sometimes in jobs for which they are over qualified. The economist Herman Daly, then working at the World Bank, pointed out that if capital does not move to the developing world, then the developing world will move to where the capital is (quoted in Bridger, 1996). One of the main challenges for ergonomics in developing countries is to recruit and retain suitably qualified personnel and provide them with the resources they need. There are many ways that funding can be obtained to achieve these goals. Some have already been discussed. Further options, worthy of consideration, include the establishment of strategic partnerships between universities in IACs and IDCs to develop joint programs of teaching and research. Universities in IACs might benefit by increasing their access to research projects and to a larger student body, while IDC universities might benefit through improved access to research funding (rather than development aid). At present, many ergonomists from IACs visit IDCs to present courses and workshops. These arrangements need to be deepened, with teaching linked into collaborative research and postgraduate training programs. Finally, collaboration should be truly collaborative, negotiated, and benefit all parties. It should not be based on the one-sided "donor–recipient" model, which is so often found in international collaborative arrangements.

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31

Starting a New Cottage Industry Factory in the Philippines

Hal W. Hendrick

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31.1 Introduction

Some years ago, I was living temporarily near Angles City, the Philippines, teaching several graduate courses in organizational behavior and human factors/ergonomics at the U.S. Clark Air Force and Subic Naval Bases. The courses were part of a University of Southern California (USC) MS program in systems management. A bright, hard-working Pilipino man, whose first name is Fred, was employed by USC to maintain the house which was rented for us by the university. Over the course of my first several weeks there, I came to know that Fred previously had worked in a cottage industry factory, finishing the many interesting kinds of Philippine baskets to be found throughout the country for sale in local retail shops and for export to the United States. He also had built rattan furniture in the factory, even helping to design some pieces. His long-term ambition was to eventually have his own factory, but he did not have the necessary funds to get started.

At the time, my wife and I were living near Honolulu, Hawaii where I was a faculty member at a USC minicampus nearby. My wife was looking for an opportunity to start some kind of business of her own when we returned from the Philippines. It thus occurred to both of us that we could construct a small factory near Angeles City and give it to Fred to manage, along with his wife, Lilia, who also was a bright, hard-working person. Our notion was that Fred could manage the factory and Lilia could handle the administrative tasks, such as keeping the books, purchasing the baskets, rattan, and other materials, and handling collections and payments. Our plan was to ship the finished baskets and rattan furniture by container to Honolulu, where we would open a wholesale/retail outlet, which my wife would operate and manage. Fred and Lilia would actually be given ownership of the factory, but my wife and I would serve as its Board of Directors.

Fred and Lilia were very enthusiastic about the idea and, accordingly, we mutually designed the factory with Fred and had it constructed. Essentially, it was approximately a 600 square foot concrete block building with a metal roof. Inside were several workbenches, power saws, drills, and hand tools. There also were storage areas for both the finished and unfinished baskets and furniture, and for rattan. Outside there was a work area for finishing the baskets and furniture, and a loading area where container trucks could pull in. By local standards, it was a very nice cottage industry setup. Fred hired seven additional workers, and he and Lilia purchased the necessary raw materials. With my help driving an old Ford F-150 pickup all over the island of Luzon looking for a wide variety of baskets, we purchased our first group and made arrangements with local basket makers for additional ones to be made and delivered to the factory at regular intervals.

At first, things seemed to go well, with our first group of baskets and various pieces of rattan furniture being of high quality. We also made the somewhat complicated bureaucratic arrangements for shipping our first container to Honolulu. Subsequently, however, three major problems emerged, which we learned about 15 months later when I again returned to teach two courses on the U.S. military bases. The first problem was a high incidence of worker injuries, and related ergonomics and safety issues. The second was comingling of personal and business income; the third was a serious cultural dilemma for Fred and Lilia.

31.2 Problem 1: Worker Injuries and Related Ergonomics and Safety Issues

First, I learned that the eight factory workers had suffered an average of one small injury per week and one lost time injury every two months. When I investigated the factory setup and operating procedures, I was shocked to see that the workers were oblivious to the basic concepts of safety that those of us in the industrialized world grow up simply knowing. For example, extension wires hung down across the workbenches where they could be cut by the power saws or damaged by hand tools or hit by the items being constructed. In some cases, there were breaks in the extension cords' insulations—apparently from having been cut or damaged. Knives used for cutting bamboo strips or trimming baskets were being used in very unsafe ways, hence causing a number of the injuries which had occurred. It had not occurred to me that these workers all had grown up in very poor rural agricultural communities where some did not even have electricity. Thus, they could not be expected to know many of the basic safety practices so essential to factory work.

To deal with this problem, I conducted a two day ergonomics and safety workshop with Fred and the one other worker who spoke fluent English. As part of that workshop, we did a hazard analysis of the workshop's physical layout and of the worker practices. In addition to the safety problems noted above, we found many of the kinds of problems also found in industrialized country work places, such as tools and equipment situated where their use resulted in awkward postures or excessive lifting, baskets being dipped in solution to kill bugs imbedded in them where the dipping container was placed on the ground and the workers had to stoop to dip them for long periods of time—perhaps dipping several hundred baskets, one at a time, and an unsafe setup for spraying the baskets and furniture with stain or other finishes.

After making corrections to these unsafe conditions and procedures, Fred then taught the other six workers in their native languages (most spoke Ilokano as their first language). As a result, minor injuries dropped to one per month and, over the next two years that I personally monitored the factory operations, we had no lost time injuries. A side benefit was that Fred used this new knowledge of ergonomics to refine and improve some of our rattan furniture designs to enhance comfort and usability.

31.3 Problem 2: Comingling of Personal and Business Income

Although I found Fred and Lilia to be scrupulously honest, I had failed to consider their lack of knowledge regarding keeping personal and business finances completely separate. Given their background, it seemed natural to them to treat both as the same. After all, it was their factory, so why keep the finances separate? Among various problems this caused, such as taxation accountability, they ultimately were unable to establish a clear, auditable accounting, and control of business income and expenses. As a result, my wife and I explained the importance and practical reasons for separating business finances from their personal income and expenses, and helped them set up proper bookkeeping and financial control procedures.

31.4 Problem 3: Cultural Conflict

This third problem was the most serious one for Fred and Lilia personally, as, in spite of an otherwise excellent marriage, it almost resulted in them getting a divorce. Fred and Lilia both came from a poor rural community, where the cultural norm was for extended family members to share whatever wealth they had with one another. Because of the success of the factory business, Fred and Lilia had moved up into the middle class by Philippine standards, and had built a nice home for themselves. When their rural family members learned of their economic success, they descended on Fred and Lilia *en mass*, expecting Fred and Lilia to share their new-found wealth with all of their extended family—even their new home. Lilia felt they needed to follow their rural cultural norm and share their income and home; Fred felt their modern urban culture did not require that; and further, in spite of their hard work, their financial resources would be so depleted that they would revert to being forever poor. Ultimately, together with some counseling from my wife and myself, they reached a compromise solution. They provided portion of their income to other family members, but retained the rest, and their home, for themselves and their three children.

31.5 Conclusion and Lessons Learned

I believe my personal example of a person from an industrialized country starting a cottage industry illustrates a very important lesson for others. Namely, it is important to first learn about the IDC culture in which you are proposing to start or support the starting

of a business with local personnel. With respect to safety and ergonomics, understand what exposure to, and knowledge of, safe workplace layout and operational procedures the workers possess from their backgrounds. Having done so, identify the required ergonomics and safety training, and provide that training.

With respect to financial management, determine what knowledge of basic bookkeeping and financial administration person(s) responsible for this function possess, and provide any necessary training to enable them to perform this function competently. Finally, study and anticipate any conflicts that may occur for the owners or managers as a result of their culture, such as occurred in this case, and discuss and resolve with the owners or managers in advance how they will handle those conflicts when they occur.

In conclusion, had I had the foresight to see these things when I first financed this manufacturing business, it would have prevented a number of injuries, resulted in better initial financial management of the business, and avoided a highly stressful and difficult cultural conflict for Fred and Lilia. I hope my "lessons learned" will help others reading this book avoid similar pitfalls.

32

Experience of Teaching and Researching Ergonomics in Germany and in South Africa

Matthias Goebel

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32.1 Introduction

A major limitation in discussing ergonomics in the context of different regions of the world is the lack of common experience. Facts and data may explore and reflect the nature of ergonomics within a given environment, but as ergonomics is always framed by a specific sociocultural environment we have to consider the nature of ergonomics in multicultural as well as multidisciplinary ways. A practical obstacle to cross-cultural comparisons of ergonomics exits in the extent to which one is able to comprehensively overview the compared cultures in both a quantitative and qualitative manner. Success in this endeavor is linked to an individual experience that, again, has its experiential limits according to the individual's biography. International exchange may broaden the view, but it has its limitations because of the inherent difference between a reader or visitor's perspective and a responsively interacting perspective. This is a challenge for all domains which are linked to a cultural environment as part of a study (Kaplan, 1995). It is particularly relevant

when individuals discuss regions that have very different developmental and cultural backgrounds, for example industrially developing countries (IDCs) compared to industrially advanced countries (IACs) (O'Neill, 2000). Understanding ergonomics at the level of international exchange thus rests on the extent to which one can bridge the gap between socioculturally different regions.

The author has had the opportunity to experience an academic education and career in Germany, before moving to South Africa to take over a position of responsibility in academia. Both experiences cover research and teaching as well as application and consultancy projects. This is supplemented by some research experience in Korea, representing the Asian continent. The present contribution is aimed at outlining characteristic differences between IDCs and IACs based on personal experiences in South Africa and Germany. Of course, this is a sample case and the perspective is mostly limited to those two countries. Ergonomics programs and their organizational links to cognate disciplines will not be discussed here. Those structures depend on the evolution of the discipline in different educational contexts (Strasser and Zink, 2007), and hence are related to the context of the education system rather to the characteristics of IDCs and IACs.

The following contribution outlines (in terms of the level of ergonomics sophistication) the different conditions pertaining in two cultures of very different socioeconomic and educational levels as well as work ethic: namely Germany and South Africa, in as much as they represent IACs and IDCs. This is followed by a consideration of ergonomics in research and teaching under these different conditions, with different approaches. The final section is then devoted to future perspectives.

32.2 Developmental Background

As in most other countries in Northern Europe, the development of ergonomics as a science started in Germany after World War II with the establishment of ergonomics societies in the early 1950s (although much research in this area had been performed long before). The rapid industrial growth during the postwar era propelled the need for ergonomics contributions for both economic as well as humanitarian reasons. During the 1960s, several German universities established departments and professorships dedicated to ergonomics. Since then, the focus of research has broadened due to new knowledge explored, new forms of organization evolving, and new technologies introduced. As a consequence, further research groups and university departments were founded to extend from primarily physiological research to psychological, organizational, engineering, and design issues.

In South Africa, an ergonomics society was formally established in 1984. Since then, ergonomics has been a focus of research at different institutions and now covers varied topics. However, the scope of the field is limited compared to Germany. One reason for this is the smaller number of departments and researchers, and the shorter time during which research has been conducted (approximately 25 versus 50 years). The ergonomics society in Germany has almost 10 times the membership of the South African society, although Germany has less than double the population of South Africa. In this regard, the per capita number of ergonomists in Germany can roughly be considered as average for Europe, although there is still a north–south gradient between European countries. This disparity results in a wider coverage of more diverse research topics in German ergonomics and at the same time, a more specific orientation of specialist researchers.

Both countries, South Africa and Germany, have recently faced a significant turning point in their political history. In 1994, the South African apartheid system was replaced by a democratically elected government, while in Germany the Berlin Wall was demolished five years before. Both events have had effects on the development of ergonomics in these countries. Germany, during the phase of separation, developed two different systems of ergonomics research. In the Western sector, ergonomics development was more application oriented and holistic; in East Germany more basic and fundamental research was carried out. After the reunification of East and West Germany, combining both ergonomics systems was technically not too difficult, although social and economic differences still persist in the population. On the other hand, South Africa was in political and economic isolation during apartheid. Although this did not apply as much to scientific activities, it must have had an impact on the application of ergonomics in the industrial field because of the particular conditions of operation. An important difference that is typical of those between IACs and IDCs results from the way ergonomics was, and continues to be imported into the country. Whereas in Germany, the discipline of ergonomics was developed to suit internal needs, in South Africa ergonomics was mostly imported via research exchange and the industrial practices of international companies. However, unique contributions have been made here as well.

32.3 Conditions for Ergonomics Application

32.3.1 Socioeconomic Background

IDCs are primarily associated with a lag in technological and economic development. The South African situation is, however, unique to a certain extent, for a change in leadership and participation occurred after apartheid was overthrown in 1994 and the privilege of the white race was replaced by a democratic constitution. During an apartheid, the country, although politically isolated, was technologically up-to-date in some areas, though out-of-date in others. Since then, a transformation of the society has taken place; however, this process is still far from being either stable or completed. It does not reflect a smooth transition from a poor rural society (with a high percentage of manual work) to a wealthier industrialized society (which uses and produces state-of-the-art technology); rather different technological and social developments run in parallel in different sectors.

Although a country's development is mostly characterized by economic and technological criteria, educational and social developments are essential as well, even though these are much slower to change due to inertial delay in educational and cultural development. Thus, a more complex view is required than is provided by the nature of a simple developmental backlog if one is to understand the bigger picture. To characterize the development of South Africa with respect to ergonomics, a differentiation into five sectors seems appropriate:

1. *"High-tech" industry*

This part of the South African economy is mostly linked to international companies and uses state-of-the-art technology and corresponding workstation design (seen in parts of the automotive, aviation, chemical, and food-processing industries), mainly in large modern plants. However, not much technology is developed *in situ*, and imported equipment and technology are mostly used. As a consequence, ergonomics criteria are referenced to

European or U.S. conditions (e.g., for anthropometric data) without further evaluation of appropriateness to local conditions (see Wyndham, 1975, for some relevant differences). The application of ergonomics in the main complies with international standards as companies mostly apply global strategies. However, occupational standards are considered in accordance with local legislation. Furthermore, in many cases, it is not the entire production system that is replicated but only the central lines. Supporting logistics are often provided which accord with local, not overseas standards.

2. *"Standard-technology" industry*
This part of the South African economy makes use of established technologies that were either imported after being formerly used in IACs (e.g., old production lines) or low-cost equipment assembled or produced locally. The technological standard corresponds largely with what pertained in Europe in the 1960–1980s, although more recent technology is included where necessary. This sort of system design is widely applied in the automotive industry, automotive supply industry, food industry and (government) hospitals, most of which are medium-sized companies, branches, or plants. Consequently, ergonomics at these locations corresponds to conditions of the past in IACs, often demanding awkward body postures of workers, high activation forces and exposure of workers to significant noise and heat. Basic organizational and occupational health standards are, however, mostly met.

3. *Small-sized industries*
Many small-sized industries provide specific production components, and diverse other services. Working conditions vary considerably more than in larger industries, and there is a high incidence of repetitive tasks. Yet, in this sector, preventive ergonomics seems to be almost unknown. Things tend to get attention retroactively only in cases of occupational injury.

4. *Rural work and the exploitation of natural resources*
Rural work is organized from an individual level to large companies (e.g., in forestry), and the exploitation of natural resources (e.g., mining) is mostly the province of large companies. In both large-scale agriculture and mining, machinery is used for heavy loads and tasks which cannot be managed by individuals. However, all other tasks are performed manually as far as possible, using simple aids or tools (such as hoes and hammers) or in rural conditions, with animal-powered assistance. The reasons are economic and historical; machinery is not easily available and is expensive because of the special equipment needed for dedicated purposes. Further, advanced machinery is sensitive to the harsh conditions in which it is operated, and maintenance skills are rare. In contrast to this, manual labor is relatively cheap and provides employment for low-skilled people. Such work can be very strenuous, involving force exertion, awkward body postures and exposure to harsh environmental conditions of heat, cold, dust, and noise. Although extensive research has been performed in this domain over several decades (particularly in mining, forestry, and agriculture), much research is still needed. Application of ergonomics is mostly considered for legal (occupational health) reasons in larger companies and very little research has been conducted relative to small-hold or subsistence farmers. More advanced ergonomics interventions are hardly practiced, although experience shows that there is still huge unexplored potential (e.g., see Christie, 2006).

5. *Casual/supplementary labor*
In IDCs, casual labor is a subsistence necessity, or a crucial means of improving living standards to gain extra income for the many people who have minimal resources or are

dependent on social grants. Subsistence work takes many forms; most involve farm-labor work or handcrafting. Ergonomics plays a minor role in this sector, as this is very much the result of *ad hoc* informal work involvement of individuals. Apart from the direct consideration of ergonomics, an important interference effect has to be considered if casual work is undertaken to supplement a regular job. As work strain and health impairment necessarily result from the activities performed, this has to be considered in risk assessment and health monitoring in companies.

In South Africa, all five sectors contribute significantly to the economy, indicating the wide disparity of (formal and informal) working conditions, and demonstrating coexistence of very advanced technologies and very traditional forms of work. However, in Germany, the first category (high-tech industry) is by far the most dominant and exists in medium and large companies, complemented by small-sized industries (the third category) mainly as local service providers. The main reason for this development in Germany is that wages are relatively high, even for low-skilled work, so that all other forms of work have been automated or transferred ("exported") to other countries with lower labor costs. The fifth category, casual (supplementary) labor, is operative even in IACs as a means of reducing expensive service and maintenance bills. However, ergonomics is not prominent throughout Germany. Although the term and its main concepts are known by large parts of the population, most small companies and organizations do not practice ergonomics actively because of lack of knowledge and the fear of costs involved. Germany engages sophisticated technology and organizational infrastructure in a very competitive environment. It is a relatively smooth process that requires extensive work to achieve slight, but crucial, progress beyond existing levels. However, small differences may have a large impact, for example when it comes to decision making for or against a production plant based on comparison of productivity figures. Ergonomics plays an increasingly important role to improve productivity, even on a macroscopic scale (considering long-term effects and health costs).

South Africa, like many IDCs, is involved in catching up in terms of introducing existing technologies (although original, state-of-the-art contributions are also made in specific fields). Thus, the balance between the five aforementioned categories is changing, and the speed of progress is constrained by educational, economic, social, and cultural factors rather than by technological progress. However, the process of change is considerably faster than in IACs. Further, when considering individual cases, developments may occur as stepwise increments rather than gradually, by switching to new technologies or new forms of service provision. Another consequence of this type of development is an orientation to adapt existing technologies and practices from IACs to the local context. Although one might argue that there is a lack of incentive to enforce original ideas, one has to be aware of the inertia of the educational milieu which must develop concomitantly with industrial progress: traditional forms of work are mostly physical in nature and provide employment to the bulk of the unskilled or semiskilled populace. As more advanced methods of production are applied, more skilled, better trained employees are required to operate the technology. Thus, while the nonavailability of skilled personnel is a central bottleneck for further development, the labor-intensive scenario ensures a living for unskilled workers.

Although labor costs are very low in South Africa compared to IACs, this is not necessarily reflected in the total production cost. In respect of production cost-per-unit, many South African manufacturers complain about difficulties in the face of competition not only from Asia, but also from European countries. Such costs are, as a matter of fact, affected by the degree of technology applied and other logistical criteria, and might be

biased by political objectives. However, observations show that effective output is lower than in European production plants, although most workers appear to be busily engaged. It is hypothesized that this is due to the lack of education, and more traditional and less efficient work organization in which planning and execution are assigned to different persons. An extensive ergonomics study has yet to be done that could identify the impact of ergonomics on efficiency in the local context.

32.3.2 Fields of Activity in Ergonomics

Many similarities exist between German and South African industries, for example in the design of physical work and risk assessment. However, the more macroergonomics topics of human-centered work organization, worker participation, and job evaluation are still less practiced in South Africa. This might be due to the more rigidly structured work organization applied in South Africa, but could also be due to the lack of ergonomics skills available.

Many fields of ergonomics activity reflect the needs of businesses and industry. The more engineering-oriented activities of ergonomics, such as design and usability of equipment as well as cognitive ergonomics, are practiced only in a few specific areas such as in military, mining, nuclear reactor engineering, and traffic systems. The fast development of these areas requires corresponding activities in the engineering and cognitive fields of ergonomics. For example, there is activity in the area of human–computer interaction, particularly for icon design (taking into consideration the different African cultures) and for call-center workplaces (considering the many international call centers recently established in South Africa). Other abstract and complex fields of ergonomics are still in their early stages in South Africa and face urgent need for progression, considering the poor quality of service delivery in the South African infrastructure and in the healthcare system in particular.

32.3.3 Working Culture and Worker Participation

Apart from technological and economic developments, the workplace culture has a large impact on the application of ergonomics. As a matter of fact, any historical background, as a cultural value, exerts a significant inertia against change. Particularly in South Africa, the working culture has been shaped for centuries by the colonial system and later by the apartheid system. During this period, indigenous workers enjoyed very limited rights in terms of occupational health protection, and even fewer in respect of personal participation in addressing the work-related problems. Employers did have a responsibility on a more general level to provide housing, nutrition, and other basic requirements for life. Although things have changed meanwhile toward a formal employer–employee type of relationship, the traditional way of thinking in this working culture persists in many areas and on both the employers' and employees' side.

Low-skilled work is still considered to be cheap work. Thus, efficiency does not play an important role. As a consequence, managers are not skilled in improving the effectiveness of work, and the workforce is not used to efficiency targets. Furthermore, there is a societal need to employ semiskilled people, and thus there is still not much incentive to improve efficiency. In this context, efficiency does not always have a positive connotation, while on the other hand, improving productivity is the crucial economic factor to increase wages effectively. The ethos of contempt of low-skilled work results in neglect of occupational health issues both from employers and employees, because there is an oversupply of work

replacements. South African labor legislation incorporates much of European and North American legislation, but the application of laws is necessarily delayed or incomplete as many of the industrial and commercial structures are still catching up to an IAC level. Only the large international companies run comprehensive occupational risk management programs, but this should in future extend to all large and medium-sized companies as well. From this point of view, developments are similar in South Africa compared to IACs. There is also some reluctance of companies to implement risk management issues that are not considered beneficial in the short term. The macroergonomics challenge to consider human issues holistically to reap the benefits of ergonomics is thus common to IACs and IDCs (Scott and Zink, 2003).

However, this is not the case in respect of the workers. Considering the aforementioned historical background of the work culture, employers are only slowly beginning to face their responsibility for workers' health and consequently most workers do not expect responsible conduct from their employers in this respect. Whereas IACs faced a shift in paradigm toward providing working conditions that are acceptable to "all" workers (from the 5th to 95th percentile of a population), the idea of worker selection and work hardening is still common in South Africa. This is the case where the options to ameliorate working conditions are limited due to the extreme environmental conditions, as it is evident in mining or sugarcane harvesting. In other industries, this principle is also widely applied for reasons of simplicity, availability of workforce, and lack of local ergonomics knowledge.

The aforementioned aspect of the working culture may explain why worker participation, a key element of holistically efficient working systems (Coch and French, 1948; Kogi, 1985), is still underdeveloped in South Africa. Although the traditional South African culture is very social and interactive, the concept of self-responsibility encounters obstacles at different hierarchical levels. This is due to the traditional respect for leaders in conjunction with a low educational level of many workers, deterring them from arguing with team leaders and other managers. Worker participation on the shop-floor level can be compared to the European situation in the 1970s and 1980s, even though semiautonomous working groups were implemented years ago in large international plants. On a higher level of participation, South Africa provides extensive options to contribute at the level of trade unions. The corresponding legislation is geared to overcoming legacies of the apartheid era and can be compared to legislation of some European countries in the 1980s and 1990s (Sweden, France, and Italy). However, this is mostly practiced on a formal level, such as for employment issues. Currently, ergonomic issues are rarely handled at the union level, but it looks like this may change in the near future.

32.3.4 Appreciation and Awareness of Ergonomics

"Ergonomics" is well known in Germany throughout the population, as it is in all other European countries. Although many different perceptions exist as to what ergonomics is about, this reflects the complex disciplinary structure of ergonomics activities, from physical to cognitive ergonomics, micro- and macroergonomics, theoretical and applied ergonomics, as well as industrial ergonomics and ergonomics in design. It also reflects the bipolarity of ergonomics, to remove hazardous working conditions and to focus on human-centered design. In South Africa, however, the term "Ergonomics" is only recognized by a small percentage of the population. Although public understanding of ergonomics improves with time, adequate appreciation of the contribution of ergonomics is still lacking among industrial managers. Studies by McKinnon and Negash (1998) and Goebel et al. (2008) show an almost unchanged pattern of managers' perceptions about ergonomics.

Similar inconsistencies occur for ergonomics topics: the popular perception of ergonomics, as the author has experienced it in South Africa, is very much related to physiological and biomechanical aspects of acceptability of workload and worker hardening, and to some aspects of ergonomics of consumer products. More indirect aspects of health and comfort become known later. Macroergonomics issues are hardly considered at this point in time (and are even considered as nonscientific by some researchers), although a successful series of workshops in this area was run in the 1990s. In general, ergonomics seems to be widely perceived as something foreign that is only relevant to some special niche areas in South Africa. The explanation is again historical: seeing that economic competition is still mostly based on low wages, and human factors are still perceived as a cost addition, there is little motivation to promote ergonomics issues. Second, the rapid changes in the society are managed by formal methods of administration rather than by the responsibility of experts. In this context, ergonomics tends to be reduced to a simplistic set of rules, with the consequence that its potential is generally underestimated. A third factor is the shortage of a middle-aged workforce due to the HIV/AIDS epidemic. The official infection rate is about 20% of the whole population, but it is higher for the low-skilled sector and is concentrated very much in the age range between 18 and 40 years, particularly females (AIDS Foundation South Africa, 2008). The ongoing decimation of a central sector of the workforce requires rethinking the traditional approach of just replacing exhausted workers by other strong and healthy individuals. This again will require ergonomics considerations. Overall awareness of ergonomics is still far lower in South Africa than in IACs, although progressing. One might compare the broad perception of ergonomics to that of in the 1970s in Europe. It can be assumed that the "Humanization of Work" campaigns that were run in most European countries during that period, despite a poor immediate effect (Bridger, 2003), had a very penetrating and anchoring effect for ergonomics perception and application.

32.4 Ergonomics Research in IDCs

32.4.1 Are IDCs Always behind?

As ergonomics research was initiated much later in IDCs than in IACs, the most basic concepts, general characteristics, and databases were already established in IACs before ergonomics research in IDCs had even started. One might not expect IDCs having a serious chance to catch up to IACs in terms of laboratory research. Of course, applied research which incorporates already established methods is more feasible and always welcome, although it is less valued than original conceptual and methodological contributions. Is it to be the destiny of IDCs merely to apply IAC research to local conditions? Conceptual research can be and has been performed successfully through the years in South Africa in spite of the aforementioned drawback. However, in catching up to research in IACs, there are three important obstacles to be faced: first, the preconditions for successful research have to be created in the form of people who have the required education and expertise to carry out quality research. This first requires the establishment of basic research skills. Second, many areas of ergonomics research are linked to pertaining industrial, social, and technological conditions. As those are still less developed than in IACs, research might be restricted. Third, research funding would need to promote the establishment of the

aforementioned intellectual infrastructure. But for practical reasons, seeing the needs of the country, resources have to be concentrated on research that will be effective in the short term. Such research is pragmatic or applied rather than strategic. Finally, using the rat race perspective, for IDCs to catch up to IACs and close the research gap would require IDCs to develop faster than IACs.

32.4.2 Perspectives on Contributions from IDCs

As a result of the bleak picture painted, one might ask whether there are still opportunities for IDCs to provide significant contributions to the field of ergonomics. There are in fact numerous such opportunities:

1. Ergonomics still lacks a great deal of data; this is true for basic research as well as for data on different populations. Whereas data on populations that have not been researched before could be considered as rather mundane (although very much needed), there is great potential for extended studies that require extensive experimentation which would be relatively easy due to the availability of human resources at acceptable costs which allows research to be conducted on many subjects, under different conditions. In IACs, such research requires huge budgets and would only be feasible for the most urgent research.
2. Relatively faster pace of industrial, technical, and social development in IDCs compared to IACs requires a faster development of research. This is a challenge in itself considering the need to provide, establish, apply, and develop appropriate methods at an accelerated rate.
3. In terms of application, the simplicity of many work systems and the budget restrictions of low-skilled workplaces create another challenge for ergonomics intervention. In IACs, the cost of research and intervention may be justified by the high labor and health cost of not applying ergonomics. In IDCs, ergonomics intervention has to be cheap and easy to implement, considering the lack of skilled people and limited financial resources. Furthermore, sustainable intervention requires a simple implementation and maintenance strategy which allows workers and local managers to continue using an implemented intervention. Although it is commonsense to strive for simple and low-cost ergonomics interventions (Kogi et al., 1998; Scott et al., 2003), actually doing it is very much a methodological and technical challenge.
4. The entire field of macroergonomics is very much related to the local working and business culture. Thus a simple adoption of macroergonomic concepts from overseas is likely to fail, and necessitates specific research to fit to the local conditions (mostly in terms of change management).

32.4.3 Common Challenges for Ergonomics Research

Three aspects which the author feels are not significantly different between IDCs and IACs are worth mentioning:

First, ergonomics postulates that proactive intervention in the design process is more effective and efficient than the reactive approach of correctional ergonomics (e.g., Laurig, 1980). However, most practical applications consider ergonomics only in a reactive way when problems appear. This is true in South Africa (James, 2002) as well as in Germany.

Although with time there might be a slow development toward earlier consideration of ergonomics in the design of a work system, the reactive strategy is still dominant. This seems to be inherent in the nature of ergonomics application, possibly caused by the complexity of ergonomics application in the design process (Goebel and Zschernack, 2005). Resistance to change has to be seen in this context as well, with similar characteristics in IACs and IDCs (Urlings et al., 1990). Second, the interdisciplinary nature of ergonomics involves many links to other disciplines, and in application, to other professions in the wider field (such as occupational hygiene and industrial engineering). This results in a need for clarification, where competencies from different disciplines overlap. However, the nature of the various disciplines determines their use of different terminology and method. Although slight differences may exist for the role of the different disciplines in different countries (including the effects of who came first to fly a flag), this basic challenge is common for both IACs and IDCs. Third, the positive effects of ergonomics are widely underestimated all over the world. What a public audience considers as normal productivity increase with time is to a large extent the result of improved ergonomics, although it is generally not recognized as such.

32.5 Ergonomics in Teaching and Learning

32.5.1 Attributes of the Education System

The level of secondary education in South Africa is very dependent on the school in question. Secondary schools of good standing provide an education comparable to upper-level education in IACs. This is likewise true of the quality of education at the tertiary (university) level. However, some different characteristics may be observed. The South African education system encourages much rote learning. Thus, routine tasks are performed very competently, whereas creative tasks and problem-solving skills are not emphasized as much. Over the next couple of years, this type of education system will be transformed to focus more on interactive skills. Although debate about this change is ongoing, the education system will converge toward IAC practices. As a consequence for ergonomics education, the traditional type of education provides an excellent basis for a scientific grounding in physiological, mechanical, and organizational basics. The more abstract concepts of perceptual and cognitive processes, psychological and social issues as well as holistic approaches are, however, harder to transmit. This is particularly the case for the application of theoretical knowledge in the form of problem-solving or design tasks.

Looking beyond the classroom, student life and social activities do not differ significantly from those in universities in IACs. In general, students face (or at least expect) a more structured career based on formal diplomas and certificates. Academics in IACs experience tough competition in the labor market, and therefore quickly learn to look out for niche areas and accept the ambivalence between fascinating job content and well-remunerated types of jobs. South African students, however, still face very positive perspectives for almost any academic degree, and thus tend to opt according to personal preferences. These are mostly either fascination with a subject or consideration of a classical, well-defined academic career (such as teacher, lawyer, or accountant) pathway. In this context, ergonomics requires a particular type of marketing because it is not commonly known and it develops its fascination with time and experience rather than at first glance. Studying low-skilled work is very much associated with darkness, dirt and heat, and thus

not very popular. Furthermore, most students do not have personal experience of this type of work at all and only learn of its existence at university. The aforementioned conditions are subject to change in South Africa as ongoing "race engineering" (target quotas for employing nonwhite and white as well as female and male applicants) impacts career decisions and future perspectives of academics. Similar to the situation in IACs, many professionals discover the need for ergonomics only with experience and thus there is a permanent request for postgraduate education in ergonomics.

32.5.2 Chicken-or-Egg Problem of Establishing Ergonomics

Historically, the development of ergonomics in IACs has followed industrial and technological progress (Helander, 1997). As a consequence, the aims of ergonomics, as well as the requirement to consider ergonomics knowledge, are widely understood. Ergonomics education and experience are available in IACs according to the laws of the market place. Although this is true, deficits may still exist in the application of ergonomics, and the need for ergonomics knowledge fluctuates over time.

In South Africa, ergonomics remains widely unknown. Although ergonomics education and research started almost 40 years ago, the public knowledge of this field is still severely limited. This is mainly due to the fact of a very limited perceived need for ergonomics for a long time. As a consequence, the demand for education in ergonomics was rather low, which kept the distribution of knowledge about ergonomics low. Is this just a stable balance between request and availability of ergonomics competencies following the laws of the market place? The author contends that it is rather a consequence of the chicken-or-egg problem. Although nobody doubts the sense of ergonomics, it is still a challenge to break the spiral of ignorance of need by educating the public about the benefits of ergonomics and by convincing students about the development potentials in this domain.

32.6 Future Perspectives

In South Africa, any positive development depends on the political and social stability that may or may not be obtained in the future. The author is optimistic that the challenges can and will be mastered, although glitches will inevitably occur. In the following scenario, a positive development is assumed, otherwise speculation is pointless anyway.

In the future development of South Africa, ergonomics will play an essential role in fostering economic growth and in ensuring consideration of human rights at the workplace. A convergence toward conditions pertaining in IACs is assumed, but only over decades to come. In the interim, we face a two-pronged approach to ergonomics, assimilating existing knowledge from IACs while carrying out original research specific to local conditions. Initially, a great deal of basic research has to be undertaken to provide comprehensive data, such as anthropometric tables, force maps, motor skills analyses, and perceptual performances characteristics of various population groups. Further, concepts of system design, both for cognitive behavioral aspects and for macroergonomics, need to be established and implemented. In this context, many endemic areas of ergonomics application will have to be explored, particularly via joint interdisciplinary research. Although many conceptual basics can be derived from existing research, there is still much that is unexplored relative to the local context. One ongoing challenge in the future is the need to provide basic

ergonomics appropriate to the less advanced technological and economic level that is still prevalent in many areas. In terms of formal application of ergonomics knowledge (e.g., for education and certification as well as risk assessment), there is, however, a strong need to comply with international standards.

How can this be supported? As knowledge transfer has to be context sensitive, simplistic transfer from IACs to IDCs is not appropriate. Context-specific knowledge is what is required. The most effective solution would be an exchange of experience which would develop researchers from IDCs as well as involving input from researchers from IACs who have the required experience. Cooperative research and student exchange programs could be very helpful in this regard. In summary, there is a lot of potential not only for IACs, but also for IDCs to provide significant contributions to the development of ergonomics worldwide.

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33

Managing Low Back Pain Risk in Industrially Developing Countries

William S. Marras

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33.1 Introduction

Low back pain (LBP) continues to represent the leading musculoskeletal disorder in the industrialized world (Marras, 2008). While LBP incident rates have been well correlated with the work environment in economically advantaged countries (NRC, 2001), far fewer efforts have studied the relationship between work and LBP in industrially developing countries (IDCs). One review of the literature reported that LBP rates vary by more than twofold between low- and high-income countries. In addition, within low-income countries, LBP rates were found to be higher among urban populations than among rural populations with an even larger disparity observed in particular worksites within cities (Volinn, 1997). This study suggested that LBP prevalence may be rising among industrially developing urban environments. While these findings present some interesting suggestions, one must consider the fact that it may be extremely difficult to collect data on LBP rates in IDCs. Therefore, conclusions based upon potentially incomplete data must be interpreted with caution. Yet another study suggests that cross-cultural differences in the self-perceived dysfunction among LBP patients may explain the large differences in

reporting rates (Sanders et al., 1992). Regardless of the true rates of LBP in IDCs, it is clear that, worldwide, LBP continues to lead to functional disability, a reduction in the quality of life for the sufferer, as well as lost productivity and reduced work quality.

This chapter reviews the contemporary understanding of LBP work-related causality with the objective of understanding the conditions that can increase the risk of LBP and the actions which can mitigate this risk. While much of the current LBP research uses sophisticated instrumentation and computational modeling methods, an attempt will be made to reduce the state-of-the-art science to practical terms applicable in developing regions. Thus, technical discussion regarding biomechanics and LBP will be avoided.

33.2 What Do We Know about LBP Causality?

Traditionally, it has been assumed that much of LBP was associated with over exertion during lifting and material-handling activities. A large body of literature investigates this association and many volumes that have been written articulate the relationship between LBP and physical work-related risk factors. Physical work-related factors typically consist of manual material handling, frequent bending and twisting, heavy physical load, static work posture, repetitive movements, and whole-body vibration. A recent assessment of the literature has evaluated these risk factors in terms of attributable fractions. The attributable fraction indicates the amount by which LBP would be reduced if the risk factor were removed. The attributable fraction for the six physical work-related risk factors mentioned above range from 11% to 80% (NRC, 2001).

It should also be recognized that a large literature exists that attempts to explain how LBP is associated with psychosocial factors. There are two types of psychosocial factors which relate to the workplace as well as to the individual. Work-related psychosocial factors related to LBP consist of high job demand, low decision latitude/control, monotony, low social support at work, low job satisfaction, high perceived stress, high perceived emotional effort, perceived ability to return to work, and perceived work dangerous to the back. Recent analyses of the literature indicate that the attributable fraction for these variables range from 17% to 69% (NRC, 2001).

Yet another body of literature addresses the relationship between individual factors (including individual psychosocial factors) and LBP. The individual psychosocial risk factors consist of depression or anxiety, psychological distress, personality factors, fear-avoidance-copying, and pain behavior/function. The attributable fraction associated with these factors range from 14% to 63% (NRC, 2001). In addition, individual genetic factors are expected to play a role in the development of LBP. While the effect of genetics is difficult to study relative to LBP, potential pain correlates such as disc narrowing due to genetic influences have been reported to be between 3% and 56% (NRC, 2001).

33.3 Human–System Response and Back Pain

At first glance, it may appear contradictory to suggest that these three bodies of literature are all associated with LBP development. In fact, significant debate has occurred that pits one category of risk factor against another. However, one must consider that these

factors are not mutually exclusive or exhaustive. In fact, it is highly likely that all of these categories of risk factors interact strongly with each other. Therefore, under realistic conditions, we are typically dealing with a combination of these factors and it is important to understand how the various risk factors contribute to the system response. Studies have shown that physical risk factors increase spine loading by increasing antagonistic muscle coactivation (Marras, 2008). As muscles counteract the physical loads (external to the body) that a worker manipulates, the reaction of these muscles mostly defines the forces that are experienced by the spine. When workers are exposed to physical risk factors (e.g., heavy loads, twisting motions, and bending actions while lifting), the trunk muscles coactivate to maintain spine stability as well as to support the external load. This coactivation of the trunk muscles means the muscles are "fighting" each other to produce the necessary net external moment. However, this coactivation also greatly increases the force imposed upon the spine tissues. These large forces then lead to pain by breaking down the tissue, stimulating pain receptors, and/or leading to a biochemical response that makes the tissue more sensitive to pain. Interestingly enough, there is also evidence that psychosocial factors can lead to a similar trunk muscle coactivation response. Studies have shown that when some workers are exposed to work-related psychosocial stress, they also tend to increase their trunk muscle coactivity and this response can lead to greater spine forces. However, these responses also appear to be conditional upon individual factors such as worker personality profile (Marras et al., 2000; Davis et al., 2002). Hence, most risk factors appear to trigger a common spine loading mechanism.

The causal pathway described suggests that LBP risk must be considered as a system. The mix of physical risk factors, individual factors, and workplace psychosocial risk factors works together to alter the trunk muscle coactivation response. This coactivation determines the spine load, and we expect that the ability of the worker to tolerate the spine load is influenced by genetics, tissue strength, age, and other individual factors. Hence, to control LBP risk, we must appreciate the system's influence due to all these risk factors. From a work-design standpoint, there is little that can be done regarding individual factors short of worker selection. However, it is extremely difficult to determine the criteria to be used for worker selection. Traditional measures such as strength and size may have little to do with a worker's ability to tolerate tissue load. Many employers who have attempted to control LBP through worker selection have not been successful. Therefore, the only categories of risk factors within an employer's control are physical work exposure factors and work-related psychosocial factor exposure.

33.4 Chronic LBP Pathways

While we suspect that there are numerous physiological sources of LBP, most agree that back pain can be categorized into muscular- and structural-based pain. It is believed that muscular-based pain is a result of forces imposed upon the muscle that exceed the strength of the tissue. This leads to muscle fiber disruption, inflammatory responses, pain stimulation, and eventual healing. As the muscles are rich in blood supply, healing is often achieved relatively quickly and if the muscle is permitted to rest sufficiently the muscle becomes stronger. This muscular pathway is typically less troublesome when designing work. However, if adequate rest is not permitted, this sequence can lead to biochemical changes that can result in chronic pain. Hence, proper work/rest cycles are an important

part of work design and depend upon the magnitude of the loads imposed upon the worker as well as the frequency of loading.

A more serious chronic pain pathway for LBP involves the structural-based pain pathway as this can involve structural changes related to permanent tissue damage and neurologic compromise. To understand this pathway, it is necessary to understand how the spine's discs receive their nutrition. The spine consists of a series of bones (vertebrae) separated by soft tissue discs. These discs are comprised of multiple layers of fibers that contain a gelatinous core (nucleus). Unlike most parts of the body, the disc has no direct blood supply and few nerve innervations. Instead, the disc receives nutrients from the surrounding vertebrae. A thin membrane (endplate) between the disc and the vertebral body regulates the nutrient flow. However, when spine loads become excessive, the endplate can develop micro-fractures. As there is little nerve innervation in the disc, the micro-fracture is not perceptible to the worker. If the work conditions result in repeated excessive compressive loads on the spine, multiple micro-fractures can be present due to cumulative trauma. As these micro-fractures heal, scar tissue forms. As the scar tissue is thicker and denser than the uncompromised endplate tissue, it reduces the nutrient flow to the disc. This reduced nutrient flow results in disc fiber atrophy and can eventually destroy the disc fiber. Once enough fibers experience this process, the disc loses its integrity, and the nucleus can cause a bulge in the disc. While there are few nerve receptors within the disc, the tissue surrounding the disc is rich in nerve receptors and when these tissues are stimulated by the disc bulge, pain occurs. Through this process, it is thought that cumulative trauma occurs within the spine. Unfortunately, once a disc reaches this stage of disruption, the condition is chronic and it is difficult to return the worker to an asymptomatic state. Once low back problems become chronic, they are very difficult to reverse. As the workers feel little pain during the degeneration process, they typically do not realize that they are at risk and do not complain until the damage has already occurred. Thus, there is little advanced warning that a worker is at risk. Given this process, the only logical approach to controlling LBP consists of prevention.

33.5 Understanding How Physical Factors Increase Risk

There are several biomechanical concepts that help us understand how forces increase within the spine during work. Through an understanding of these concepts, we can analyze complex work situations and help understand how and why we should change workplace designs.

33.5.1 Minimize Moments

A moment is defined as a force multiplied by a distance. Just as a first class lever can balance a heavy load with a moderate load applied at a large distance from the fulcrum, the reaction of the trunk muscles (and subsequent spine forces) rapidly become excessive as the distance between the spine and the object lifted (moment arm) increases. Hence, the farther from the spine an object is when lifted, the more the loading on the spine. This demonstrates that the force experienced by the spine (and the potential for chronic LBP) is influenced greatly by the distance of the object from the spine and NOT just by the weight of the object. Therefore, the same weight may either be safe (if held close to the body) or

dangerous (if held far from the body) depending upon where it is located relative to the spine. Field studies have shown that moment is the most predictive single variable in LBP incident rate prediction (Marras et al., 1993).

33.5.2 Muscle Length–Force Relationship

The ability of a muscle to generate force efficiently is directly related to the length of the muscle when it is activated. Because of the relationship between the small muscle filaments, it has been well established that the muscle is more powerful at its "resting" length. The resting position of the muscles is generally achieved when the body is close to the fetal position. As the muscle lengthens or shortens from this resting position, an inverted U-shaped relationship is present. Hence, this means that when the back muscles are elongated (as when reaching to ground level) or shortened (as when reaching over head), they are at a severe strength disadvantage. If the force imposed upon the muscles exceeds its strength, then the muscle is at risk of injury and overexertion. In addition, spine stability can be compromised especially when the trunk is flexed forward. This can lead to structural compromise as the spine's support system partially disengages when flexed.

33.5.3 Velocity–Force Relationship

The faster a muscle is shortening, the less force the muscle can produce. This relationship has implications for dynamic work. The faster workers are moving the less strength there is available to the muscles and the greater the risk of injury from muscle overload as well as instability of the spine (structural compromise). This relationship also needs to be considered when assessing the risk associated with a work place. However, this concept should not be confused with the concept of momentum. It is also possible to minimize tissue load by accelerating a load while the muscle is at an optimal length and then releasing the load through the rest of the range of motion. An example of this would be tossing a load onto a truck bed.

33.5.4 Loading Frequency

It has also been well established that the more frequently a task is performed throughout the day, the less capable the worker is of sustaining the same level of work. Studies have shown that as the frequency of loading increases spine loading increases as a function of time (Marras et al., 2006). This increased spine loading results from increased levels of trunk muscle coactivation that occur at certain frequencies of lifting. In addition, as the muscles fatigue, the muscle recruitment patterns change and make the spine more susceptible to instability. These biomechanical reactions become the basis for cumulative trauma to the spine.

It is also important to realize that these risk factors can interact and exacerbate the risk to the low back. For example, if a worker flexes the trunk forward to lift an object from the ground not only do the back muscles operate at a lengthened (weak) position, but the weight of the torso positioned in front of the hips increases the moment to which the low back is exposed. Collectively, these place the spine in a very dangerous position for LBP. As the work situations change, it is important that an ergonomist be able to systematically assess how these various risk factors collectively contribute to overall spine loading and risk. This is particularly important since different work situations and interventions

will lead to trade-offs between these biomechanical relationships. Thus, it is crucial that the ergonomist develops a conceptual appreciation for how work changes influence these interactions.

33.6 Minimizing LBP Risk through Workplace Design

Work environments can generally take the form of either repetitive "factory" work where the same actions are repeated throughout the day, or they can take the form of "field work" (e.g., construction and forestry) where the worker is exposed to a wide variety of tasks throughout the day. The work design approaches in these two environments are significantly different. In factory environments, it is possible to control the motions and positions of the worker through the placement of parts such as jigs and tools in the workplace, thus making it possible to limit exposure to the factors that can lead to LBP. Both physical risk and psychosocial risk exposures are better defined in these environments making it easier to intervene effectively. Field environments, on the other hand, are far less predictable. It is often difficult if not impossible to arrange the work environment appropriately to minimize the biomechanical risks as construction parts and supplies are not often able to be arranged in an appropriate manner. In addition, psychosocial interactions are much more difficult to study and control in field environments as these environments are constantly changing.

33.6.1 Factory Environments

The design principles for a factory style environment can be derived directly from the list of biomechanical risk concepts discussed earlier. One of the primary risk factors involves excessive moment exposure. Acceptable limits to moment exposure have been summarized by the American Conference of Governmental Industrial Hygienists (ACGIH, 2005), and also have been published in other publications (Marras, 2008) through the development of "threshold limit values" or TLVs. These limits identify different work "zones" in front of a worker and specify the maximum load to which workers can be exposed given the frequency of lift and exposure times. Maximum load exposures vary from 32 kg when placed directly in front of a worker and close to the body (within 30 cm) to 9 kg when the load is from 60 to 80 cm away from the worker. In general, the concept here is to move object as close to the body as possible when lifting and to minimize the need to twist and turn when handling objects. It should be emphasized that these limit values are intended for repetitive work. The TLVs appropriate for different work situations are shown in Tables 33.1 through 33.3. These goals can be achieved by delivering items close to the body and not requiring the worker to reach long distances to perform the task. This can also be achieved by orienting the work directly in front of the worker at about waist level through the use of shoots, roller systems, conveyors, and any other devices that can move the objects easily to an ideal position in front of the worker. It is also important to consider workpiece orientation in terms of presentation relative to the worker. Even if the worker is not lifting a piece, it is possible to impose large loads on the back by designing a workplace where the worker must reach to extended positions to perform the required task.

Similarly, the concept of the length–force relationship dictates that objects should be placed in positions that optimize the muscle lengths within the back. This means that, in general, objects should be handled at heights between knuckle height and below the shoulders but preferably just below waist level. As one moves away from this ideal zone,

TABLE 33.1

TLVs for Lifting Tasks ≤2 h per Day with ≤60 Lifts per Hour or >2 h per Day with ≤12 Lifts per Hour (Values Indicate Maximum Allowable Weight of Lift in kg)

	Horizontal Location of Lift		
Lifting Height Zone	**Close Lifts: Origin <30 cm from Midpoint between Inner Ankle Bones**	**Intermediate Lifts: Origin 30–60 cm from Midpoint between Inner Ankle Bones**	**Extended Lifts: Origin >60 to 80 cm from Midpoint between Inner Ankle Bones[a]**
Reach limit[b] from 30 cm above to 8 cm below shoulder height	16	7	No known safe limit for repetitive lifting[c]
Knuckle height[c] to below shoulder	32	16	9
Middle shin height to knuckle height[c]	18	14	7
Floor to middle shin height	14	No known safe limit for repetitive lifting[c]	No known safe limit for repetitive lifting[d]

Source: Adapted from American Conference of Governmental Industrial Hygienists (ACGIH), *2005 TLVs and VEIs Book*, 2005.

[a] Lifting tasks should not be started at a horizontal reach distance more than 80 cm from the midpoint between the inner ankle bones.

[b] Routine lifting tasks should not be conducted from starting heights greater than 30 cm above the shoulder or more than 180 cm above floor level.

[c] Anatomical landmark for knuckle height assumes the worker is standing erect with arms hanging at the side.

[d] Routine lifting tasks should not be performed for shaded table entries marked "no known safe limit for repetitive lifting." While the available evidence does not permit identification of safe weight limits in the shaded regions, professional judgment may be used to determine if infrequent lifts of light weights may be safe.

the weight of the object lifted should be reduced. These limits have also been combined with moment arm limits to define lifting zones and the recommended limits can be found in the previously mentioned TLVs (see Tables 33.1 through 33.3). The TLVs indicate that the acceptable weight of objects lifted from low and high heights is rapidly reduced and is also reduced when greater lift frequency or more extended moment arms are present. It is possible to affect the vertical height at which the work is performed by delivering the work to the worker at the correct height via conveyors or roller systems, by the use of lift tables, or as a last resort (because of the expense) by extending the reach of the worker by using lifts, hoists, or balancers. Another way to influence the lift height of an object is to employ case handles. Cases without handles must be lifted from underneath the case which requires a deep bend and elongation of the trunk muscles. However, case handles are typically placed near the top of a case. Lifting using the handles therefore reduces the required trunk flexion, thereby minimizing the negative effects of the length–force relationship as well as minimizing the added moment imposed about the spine due to trunk flexion.

The moment and length–force relationships can also be greatly influenced by asymmetric materials handling or working while twisting. However, these TLVs only address materials handling while working within 30° of the sagittal plane. Therefore, when using these limits, one should apply these recommendations only as a guideline, and discount the limits by greater amounts when twisting or asymmetry is involved in task performance.

TABLE 33.2

TLVs for Lifting Tasks >2 h per Day with >12 and ≤30 Lifts per Hour or ≤2 h per Day with >60 and ≤360 Lifts per Hour (Values Indicate Maximum Allowable Weight of Lift in kg)

	Horizontal Location of Lift		
Lifting Height Zone	**Close Lifts: Origin <30 cm from Midpoint between Inner Ankle Bones**	**Intermediate Lifts: Origin 30–60 cm from Midpoint between Inner Ankle Bones**	**Extended Lifts: Origin >60 to 80 cm from Midpoint between Inner Ankle Bones[a]**
Reach limit[b] from 30 cm above to 8 cm below shoulder height	14	5	No known safe limit for repetitive lifting[c]
Knuckle height[c] to below shoulder	27	14	7
Middle shin height to knuckle height[c]	16	11	5
Floor to middle shin height	9	No known safe limit for repetitive lifting[c]	No known safe limit for repetitive lifting[d]

Source: Adapted from American Conference of Governmental Industrial Hygienists (ACGIH), *2005 TLVs and VEIs Book*, 2005.

[a] Lifting tasks should not be started at a horizontal reach distance more than 80 cm from the midpoint between the inner ankle bones.

[b] Routine lifting tasks should not be conducted from starting heights greater than 30 cm above the shoulder or more than 180 cm above floor level.

[c] Anatomical landmark for knuckle height assumes the worker is standing erect with arms hanging at the side.

[d] Routine lifting tasks should not be performed for shaded table entries marked "no known safe limit for repetitive lifting." While the available evidence does not permit identification of safe weight limits in the shaded regions, professional judgment may be used to determine if infrequent lifts of light weights may be safe.

It should also be recognized that there are trade-offs among these variables. For example, while minimizing the moment is of primary concern in workplace design, one could actually increase trunk twisting (and increase risk of LBP) by placing lift tables too close to the workers causing them to twist with the back instead of taking a step to move an object and thereby minimizing spine twisting (Stuart-Buttle, 1995). Hence, the interaction of task design decisions on all the previously discussed biomechanical concepts should be considered when designing work.

Finally, the velocity–force and lift frequency factors should be considered in work design. Here again, guidance for these factors can be found in the TLVs described earlier. While velocity–force relationships are important risk factors, there is evidence that these are uniquely defined through the work layout as opposed to individual actions (Ferguson et al., 2004). Good work-design practices (minimize travel distances, reasonable pacing, etc.) dictate the muscle velocity. Hence, this is a concept that is manipulated through placing objects in more optimal work zones, minimizing travel distance, and considering lift frequency. Lift frequency is also addressed in the TLVs discussed earlier. While many of the traditional work measurement analyses include rest allocations, it should be realized that none of these are based upon risk to the musculoskeletal system. Unfortunately, they are all based upon the concept of "a fair day's work." Hence, it is imperative that musculoskeletal-based guidelines, such as the TLVs, be considered to identify appropriate rest cycles.

TABLE 33.3

TLVs for Lifting Tasks >2 h per Day with >30 and ≤360 Lifts per Hour (Values Indicate Maximum Allowable Weight of Lift in kg)

	Horizontal Location of Lift		
Lifting Height Zone	**Close Lifts: Origin <30 cm from Midpoint between Inner Ankle Bones**	**Intermediate Lifts: Origin 30–60 cm from Midpoint between Inner Ankle Bones**	**Extended Lifts: Origin >60 to 80 cm from Midpoint between Inner Ankle Bones[a]**
Reach limit[b] from 30 cm above to 8 cm below shoulder height	11	No known safe limit for repetitive lifting[c]	No known safe limit for repetitive lifting[c]
Knuckle height[c] to below shoulder	14	9	5
Middle shin height to knuckle height[c]	9	7	2
Floor to middle shin height	No known safe limit for repetitive lifting[c]	No known safe limit for repetitive lifting[c]	No known safe limit for repetitive lifting[d]

Source: Adapted from American Conference of Governmental Industrial Hygienists (ACGIH), *2005 TLVs and VEIs Book*, 2005.

[a] Lifting tasks should not be started at a horizontal reach distance more than 80 cm from the midpoint between the inner ankle bones.

[b] Routine lifting tasks should not be conducted from starting heights greater than 30 cm above the shoulder or more than 180 cm above floor level.

[c] Anatomical landmark for knuckle height assumes the worker is standing erect with arms hanging at the side.

[d] Routine lifting tasks should not be performed for shaded table entries marked "no known safe limit for repetitive lifting." While the available evidence does not permit identification of safe weight limits in the shaded regions, professional judgment may be used to determine if infrequent lifts of light weights may be safe.

To minimize LBP risk within the workplace, biomechanical concepts must be considered in conjunction with the guidance offered by the TLVs. While other guidelines are available (NIOSH Lifting Equation, Psychophysical Tables, and static strength models), the TLVs are preferable because they combine the strengths of these various approaches into their limits while also relying on historical incident rate data. None-the-less, all guidelines including the TLVs should be used in conjunction with the analyst's judgment based upon biomechanical knowledge and understanding of the interactions between variables. Guidelines should never be used as the sole indicator of proper design as optimal design depends upon the specific work situation.

Finally, one must not forget the "human element" when designing workplaces. As discussed earlier, workplace psychosocial factors play a role in how workers recruit their muscles and load their spines. Workers are not machines. If they are treated like a machine, many will become stressed and increase their muscle cocontraction and subsequent tissue loading. Of the work-related psychosocial factors discussed earlier, high job demand, low social support, and low job satisfaction are associated with the largest attributable fractions relative to LBP. Job demand should be considered via pacing and frequency limits. While every workplace strives to increase productivity, reasonable pacing (that can be defined through TLVs) should be balanced against increased productivity. Given the cost, suffering, and reduction in work quality associated with LBP, one should

not be shortsighted in pushing workers to their physical limit. This will result in much greater costs in the long run.

Low social support typically refers to a lack of supportive interactions with a supervisor or coworkers. Management must realize that the workforce is part of a team and they should be treated as team members. This includes praise when they perform well, encouragement when needed, and understanding when personal issues interfere with the workers' attitudes. Often a little understanding will go a long way to minimizing stress, reducing spine loading, and eventual risk reduction in LBP. Similarly, job satisfaction has been recognized as an important part of an optimal work environment. That which satisfies a person is often a function of personality. However, most workers do not enjoy "mindless" work. Job content should be considered so that the worker has a sense of accomplishment at the end of the day. This can be facilitated by permitting the worker to use some judgment in accomplishing the job, even if it is as simple as selecting the correct parts for assembly or organizing of the workspace to make reaches easier.

33.6.2 Field Environments

Both the physical and psychosocial environments are more predictable and more controllable in the factory setting compared to the field setting. Field environments, on the other hand, are very difficult to control as the opportunities for proper placement of objects is rare. For this reason, most field workplaces focus on administrative controls as opposed to engineering control.

Volumes have been written about the correct way to lift and many administrative controls have focused upon proper lifting techniques. However, few of these techniques have proven effective in preventing LBP (van Dieen et al., 1999; Lavender et al., 2007). This is most likely due to several factors. First, as we have already seen, work postures and motions are primarily dictated by the layout of the work. Training workers to overcome these influences has not been proven effective. Second, as workers fatigue they gravitate to whatever lift method requires less energy which may not correspond to the "proper lifting technique." Finally, few workers appreciate the cumulative trauma nature of LBP, thus they are typically not motivated to follow proper lifting techniques until LBP occurs. At this point, LBP is often difficult to reverse. Others have attempted to control field environment through the use of lifting belts. However, the literature has been clear for some time that these do not reduce LBP risk (McGill, 1993; Wassell et al., 2000; van Poppel et al., 2004). Back belts are not recommended as a preventive approach to controlling LBP.

This leaves the idea of "working smart" as one of the only feasible alternatives to field work. In his book, McGill (2002) offers several suggestions for workers, many of which appear appropriate for field work. These suggestions include the following list:

First, avoid the end range of spine motion during work. This incorporates both the load moment and length–force biomechanical concepts discussed earlier. Thus, full flexion of the spine as when lifting from the ground or performing extreme reaches should be discouraged. We have already discussed much of the logic associated with this concept. However, workers must realize when it is particularly important to adopt good biomechanical postures in the field. Unlike training that states simple concepts such as "always lift with your legs not your back," McGill's approach would suggest that workers be particularly cognizant of when they are at high risk of tissue damage and intervene by seeking help, lifting devices, or if nothing else, ensure they employ proper lifting mechanics that would include being particularly cognizant to maintain the lumbar curve during the lift.

Second, reaction moment should be reduced. This can be accomplished by pushing and pulling in such a way that the resultant moment from the hands passes though the low back, thereby minimizing the moment about the spine. Thus, the direction of force when pushing/pulling should point through the low back and not up or down.

Third, McGill suggests diversion of the force around the lumbar spine. Techniques to accomplish this goal involve the transfer of load to the thigh so that the load is not transmitted through the spine. Examples of this would include leveraging a load on the thigh as one is manipulating a weight, pushing with the hip instead of the hands, supporting a lifted object with the knee or hip, or shoveling with the elbow resting on the thigh thereby creating a new fulcrum point. In each of these techniques, the force of the object manipulated is primarily passed to the upper leg or hip instead of through the spine.

Fourth, reduce the load through smart lifting. This includes using leverage (through pivoting) to lift a load. For example, a log can be lifted easily by only lifting one end and pivoting the load instead of supporting the entire weight of the load with the body. Workers should think about how to use leverage to their advantage and plan lifts and object manipulations.

Fifth, avoid twisting at the waist. This can often be achieved by teaching the worker to take steps with the load instead of twisting from the waist.

Sixth, break up the load into smaller loads. This can often be accomplished by unloading a crate and moving the individual contents instead of carrying the entire load simultaneously. This may take more time, but the worker will be able to have a much longer working career in the long term.

Next, eliminate unnecessary lifting. Higher level planning about the sequencing of materials delivery to a job site can minimize repeated handling of materials. It is not uncommon for a good portion of lifting tasks to be due solely to poor planning. Hence, proper planning can not only reduce LBP risk, but it can improve work efficiency and reduce costs.

Finally, the same workplace psychosocial factors discussed for factory work should be considered in the field work context. However, as field work often involves excessive load manipulation, some have indicated that psychosocial factors are overridden by biomechanical demand in these instances (Marras, 2008). On the other hand, psychosocial factors may further exacerbate the situation. None-the-less, field work often involves construction tasks and it is generally easier for workers to have a sense of job satisfaction as they can often observe the fruits of their labor. Alternatively, a lack of social support and high job demands are often significant barriers to a positive psychosocial environment, and field environment can represent social factors that are less than supportive due to the "rugged" nature of the work.

33.7 Conclusions

This review has shown that there is a strong association between LBP and work environments. However, LBP risk is a complex interaction of biomechanical factors, the workplace psychosocial environment, and the worker's individual risk factors. While little can be done about the worker's inherent individual risk, much can be done to alter the exposure to the physical and psychosocial environments to which the worker is exposed. Effective workplace design requires an understanding of how biomechanical factors interact with

each other to load the spine and use this knowledge to orient the work so that it minimizes spinal stress. In addition, one must recognize that psychosocial interactions in the workplace can also interact with the worker's biomechanical functioning. The challenges of workplace design can be much greater when field work is involved and the solutions often involve proper planning as well as helping the worker to work smart.

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34

Sustainability: An Ergonomics Watchword for the Twenty-First Century

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34.1 Introduction

One could say that this book is the culmination of two years work, but I rather see it as the "voice" of the many people around the globe who have striven in some small way to better the working life (and thereby the overall quality of life) for billions of working people in all corners of the world over the last 50 years or more. They are the unsung heroes of ergonomics! This final chapter draws on this good work to give a synopsis of the situation in industrially developing countries (IDCs) in general, with the hope of directing the energy of more ergonomists toward assisting developing nations to become more self-sustaining and able to contribute on a more equal basis to the global market, thereby ensuring universal sustainability.

Ergonomics has advanced and grown, in breadth and depth, over the last half-century and during this period national and international societies in the industrialized world have, justifiably, touted their achievements and progress with great pride. But over that same period they have been ignorant of, or have tended to turn a blind eye to, the fact that industrially developing nations urgently need to be part of this evolvement, even though the focus and application of ergonomics varies significantly from those of industrially advanced countries (IACs). This book speaks to the needs of IDCs, i.e., for global awareness, long-sightedness, and a balanced mix of ensuring rights and taking responsibility.

The IDCs comprise a vast proportion of the world's countries and about 75% of its population. This huge biomass alone justifies them being a higher priority for ergonomics

than IACs. We have seen in this volume how technological developments, which have relied heavily on ergonomics, along with democracy and political stability, have made the IACs (often at the expense of pillaged IDC natural and human resources) what they are today. Short-sighted self-interest cannot sustain current IAC standards, but a global concentration on IDC upliftment (via facilitation, not handouts), at least in principle, can help move both IACs and IDCs in the direction of sustainable advancement.

While ergonomics is not synonymous with democracy and political stability, everything about it has human rights, dignity, welfare, and prosperity at heart. Typically, if not uniquely, it has the potential to bring together entrepreneurs, unions, workers, "greens," producers, consumers and middlemen, shareholders, and investors, in a long-sighted sustainable development ethos in which everyone involved is a beneficiary. Indeed some years ago Hendrick (1998) argued that few other disciplines have the ability to make as great an impact on the well-being of people as ergonomics. However, the truth is that the industrially developed world has a poor record of understanding, and an abysmal record at implementing a culture of sustainable development. At the same time, the exploited developing world has a mountain to climb in democratization, securing political stability, respecting the rule of law, and in entrenching human dignity—quite apart from securing a standard of living anything like that typically enjoyed even by the lower middle classes of the developed world. Industrially underdeveloped countries are expected by the leaders of the industrialized world—a world which has traditionally exploited them—to climb that mountain without infringing on the tenets of sustainability which the affluent world itself does not respect. And yet, the situation is not hopeless.

34.2 Ergonomics in IDCs

Around the world, ergonomists, such as those represented in this book, toil against all odds, determined not to give up; and, they typically experience rewards IAC ergonomists only dream of, for when things could not be much worse, small no-cost/low-cost interventions often (as this book so dramatically exemplifies) reap immediate and substantial rewards. For IDC practitioners, ergonomics is not just a way of making a living, but a vocation dedicated to improving the general quality of life for the people in their diversified regions. We have seen, for example, the use of participatory ergonomics as the route to self-help initiative development for tens of thousands of Vietnamese peasant farmers. Photos of local good practices spread like wildfire, as did action checklist suggestions. But, as is typical, the real success was that the initiatives then spread autocatalytically. The cultural milieu was no doubt a *sine qua non* in this instance which, as an example, is one that begs to be taken wider afield.

34.2.1 Participatory Involvement

While it is both frustrating and enormously challenging to have to tackle countless minor superficial problems along with problems of sometimes gigantic proportions, it is also most rewarding to witness the immediate and long-term beneficial effects. It is edifying to see how a growing awareness of ergonomics has a ripple effect throughout the industries in which it has been introduced, particularly if all concerned are drawn into the process. The greatest successes reported in this book were achieved through participatory

ergonomics. In a very different world to the one we are focused on, Pfeffer (1998) of the Harvard Business School talked of "building profits by putting people first." No company, particularly in IDCs, can survive without its people, which is why ergonomics in IDCs is human rights focused. We therefore need to encourage the input and involvement of both employers and employees, from different sections within the company, and drawing on diverse levels of expertise of all those involved. It is crucial to acknowledge that floor workers have an amazing tacit knowledge of their own worksites, and when included in discussion groups they often show great initiative in offering solutions to problems they have had to put up with for years. Coordination of all stakeholders is essential for an all-inclusive participation in working toward achieving a common goal, and is unparalleled in accomplishing the betterment of the individual, the industry, and the nation.

34.2.2 Economics of Ergonomics

Once an awareness of ergonomics starts to gather momentum, so productivity improves and the financial gains to the company become more apparent. Many authors herein have stressed the need for greater appreciation of the link between ergonomics and economics, and some have made it clear that ergonomics needs to make sound business sense, so enabling management (who are generally so reluctant to come on board) to make decisions based on financial gain considerations. Ergonomics must be seen as a cost effective investment. Probably the most commonly used phrase throughout this chapter is "Good ergonomics is good economics" (Hendrick, 1996), and once we have documented more success stories so the overall benefits (financial and human) will become more manifest to all, ultimately leading to a greater commitment to ergonomics and consequently to more long-term gains or sustainability.

34.3 Sustainability

Sustainability is a concept whose time has come. Exponentially increasing populations, with exponentially increasing expectations, are becoming abrasive as they see disparity and sense exploitation. Fundamentalism breeds in these situations, and in an increasingly small world IACs are easy (and, as recent history shows, often blithely unsuspecting) targets. Against this "global village" backdrop, all fields of human endeavor must, in the twenty-first century, play their role.

More than half the population of this planet live as rural peasants, where subsistence farming is their livelihood. When things go well, more is produced than the producer can consume, and the possibility of an expanded enterprise and a better life begins to materialize. Yet only with a physical communications network (beginning as animal tracks, used as human paths and eventually made into dirt roads) can surplus assets be distributed and commerce begin. In IDCs, when anything remotely approaching a modern highway system is constructed, it is built between densely populated centers of intensive manufacturing or large-scale labor-intensive agriculture. These urban connections take no cognisance of the needs of the people widely dispersed in the surrounding habitable areas, who are often isolated from one another and require, for communication, informal modes of transport only some of which are motorized. And so the breach widens as the cost of fossil fuels becomes prohibitive for poor peasants with inevitable consequences—in Africa, for

example, foreign-owned oil pipelines are routinely plundered (often at fatal cost) by people who cannot afford fuel even for cooking.

The IACs are learning the hard way that IDC resources are theirs to withhold, and IDCs are learning, the easy way, to exert themselves. Thus intransigent, often corrupt regimes, may withhold the resources that the coddled nations have come to rely on and without which they could barely function. This exacerbates the divide, as leaders who represent quite different conceptual worlds must negotiate without full appreciation of each other's standpoints. Thus IDC degradations of the environment are deplored by IACs which have for centuries themselves shown scant concern for sustainability. There is no moral high ground here, and both IACs and IDCs no longer have a choice but to reach accord. A European's "right" to drink coffee cannot be at the expense of denied access of Central American peasants to small tracts of arable land to grow corn for the table. This places the onus on the "haves" to find ways to continue to absorb the resources of the underdeveloped world while simultaneously ensuring an equitable recompense, not to the IDC landlord supplier only, but to the people whom the supplier in turn is keeping impoverished. Corrupt elites in IDCs buy yachts in the Mediterranean while nonelites are kept in serfdom. On the principle that accessories to crime are also culpable, IACs, if their lifestyles are to be sustained, must begin to take responsibility for their (albeit indirect) roles in keeping the impoverished world impoverished.

Several contributors concur that the gap between IDCs and IACs is widening, and have noted that while the latter may be involved in some highly sophisticated ergonomics in their own countries, they are at the same time exploiting cheap labor in developing areas. Their justification for this is that although they are unable (or disinclined) to do anything about conditions in IDCs, they are at least affording the poor a livelihood. It has been starkly shown that export processing zones in which "low-skilled manufacturing jobs are transferred from industries in advanced countries to less developed countries where labor is cheap and uncomplaining" have proliferated in IDCs. As IDCs supply more to the global market the pace of work is increased, resulting in high incidences of serious injuries and even fatalities. Workers pushed to their physical limits may initially increase their output, but only at high human and financial costs in the long run, for as functional capacity is reduced not only does the quality and quantity of productivity drop off, but so does the quality of life of overexerted workers. It is self-evident that there is a clear need for worker protection and for a greater demonstration of social and ethical responsibility. Perhaps, as some have suggested, there is also a need for educating consumers to be more aware of the conditions under which their goods are made. This could have a ripple effect of improving working conditions through "responsible shopping" and applying pressure throughout the supply chain.

34.4 Macroergonomics and "beyond"

Ergonomics, by expanding from its "man–machine" past into its all-inclusive "organizational design and management" present, has, whether it likes it or not, "politicized" itself. The question then becomes when does an "organization" (and hence an ergonomist's responsibility to it) end? Large corporations (an IAC invention) lobby with, and involve themselves in, government at local, regional, and national (sometimes even international) levels. Ergonomics can no longer (though individual ergonomists clearly may) play biomechanical, or physiological, or cognitive games in formal workplace settings, as if the

humans involved were protein-based robots, unaffected at work by the outside world of which they are a part. Hence the need to do a great deal more than to simply play lip service to factors beyond the 8 h shift. We should take serious cognizance of the "compounding negative spiral" as discussed in Chapter 1, and make every effort to stop and reverse this debilitating scenario. "Sustainable development", watchword of the twenty-first century, if there is to be a twenty-second—is the only hope for a better life for all.

Although ergonomics is not about politics, the world in which ergonomists operate is. This means that ergonomics, wherever it is practised, must be socially and politically aware—in the same sense in which it is aware of, and interacts with, other cognate domains like industrial psychology and occupational health and safety. Indeed organizational design and management, now a vibrant and essential component of the whole, would never have got off the ground were it not for the realization by its founders of the fact that wider (by definition sociopolitical) considerations underpin even the narrowest of interventions.

Repeatedly in this volume we hear how macroergonomics interventions have been accepted at the "top" and "bottom" but not at the "center" of numerous companies. Many have cited middle management as being the "biggest stumbling block" because of its attitude that workers should do the physical work and they, as floor managers, do the thinking. This dichotomizing of "physical workers" and "cognitive managers," whether consciously or otherwise, exerts a top-down control in which workers are actually discouraged from thinking. It would appear that many middle managers feel threatened when workers take initiatives which they see as their role, i.e., to keep the company going at all costs. What this means is that they break, rather than forge, the only hope of a link between top management and floor workers, without which sustainability of the endeavor is not possible. Top management tends to be above-it-all, and bottom workers are pressured to tolerate abuses and dissuaded from showing initiative or interest, or otherwise enhancing their commitments, which paradoxically if developed, would ensure increased corporate success and longevity.

Some from within ergonomics circles see the existing sociocultural, political, health, educational, and economic underpinnings of the society in which they operate as extraneous, as if requiring these to be optimized before being able to intervene. We suggest that IDC ergonomists (because where they work the prevailing social deprivation is dire) are far ahead of their IAC compatriots in this, and far more attuned to design changes that take cognisance of the broader context of life for the people whose working conditions are being optimized. Ergonomists in a country like Zimbabwe can do nothing about world-record runaway inflation, but they can effect positive interventions for people living in a police state in which nothing works, politically or socially. They routinely do this in most IDCs by considering more factors than IAC ergonomists ever have to face or deal with, and by making interventions IAC ergonomists would never think of, whose effects ramify into meaningful changes in the lives of the workers involved. Even within IDCs, cultural differences are immense: ergonomists in Far Eastern countries effect huge changes at negligible expense largely because of the culture-based work ethic of the people. Ergonomists in Africa face entirely different conditions, calling for a very different approach. People laid low by debilitating diseases like bilharzia or malaria, and by barely drinkable water and poor nutrition, have no work ethic to display.

The rot of corruption, so debilitating in IDCs, is not unknown in IACs though it festers less and is better disguised and more easily expunged. The difference is of degree, not kind. And, of all adverse cycles, the cycle of corruption is perhaps the hardest to break. As the extreme dichotomy between the rich and the poor increases, the rot of corruption begins to spread autocatalytically. Several authors in this volume have shown how, in

IDCs, macroergonomics (culture-changing) interventions are harder to implement than "band-aid" microinterventions. Part of the reason for this is that local macrofactors (like company management) tend to mirror the wider (national) ethos of the society concerned. Ignorance, corruption, and nepotism at the governmental level collectively reinforce the same ethos at company management level. No wonder this book cautions that our work is intertwined utterly with politics—whether we like it or not.

Bottom-up education of workers not to tolerate abuse, and top-down education of management not to stultify their own long-term profit margins by short-term greed, is part of the package that ergonomics has to offer. To the extent that it is offered effectively, the outcome, purely as a by-product, is a small, but cumulative, erosion of societal malfunctions. So while ergonomists are not focused on saving the world, their local efforts at sustainable positive change within the working environment do have salutary wide-reaching by-product effects.

Many, and sadly some influential ergonomists with "Western" mindsets are among them, see IDC reliance on unskilled manual labor as a needless problem easily mechanized-out, if only the will was there. What they fail to see is the effect of mechanization on job loss. When longshoremen in an average African port, such as in Namibia, are replaced by forklift loaders and cranes, thousands go hungry. We have seen how, in some cultures, a (rare) breadwinner is expected to support a wide extended family of indigents. Glibly passing the buck to effete governments in many IDCs is not solving the problem. Governments wishing to climb out of huge debt-repayment obligations, saddled with massive HIV/AIDS and other epidemics, struggling with famine, internecine conflict, endemic corruption, high crime rates, etc., are ill-equipped to provide technical education to their people or even to facilitate acquisitions of labor-saving machinery which would increase productivity. In truth, Africa is strewn with imported machinery (which IACs have been only too eager to sell), lying derelict because no maintenance infrastructure was built-in initially.

Not that all the problems listed above are the responsibility of IACs to solve. No IDC exists which would tolerate infringements of its sovereign rights. But all must in turn accept their sovereign responsibility to secure their own upliftment. And it is precisely here that the IDC ergonomists come into their own. Conversant with their own cultural idiosyncrasies, the educational level of their peoples, and their endemic needs and aspirations, they are best positioned to make positive contributions to productive well-being at the workplace. This volume is a testimony to the good intentions and the struggles of ergonomists from the less advantaged countries of our global village. While some ergonomics "experts" of IACs may look down on some of these endeavors, the wise, and well-read, know that their own islands of excellence risk being swamped (directly or indirectly) by the problems of IDCs, some of whose malfunctions are matched only by their menacingly real acquisition of destructive technologies and some of the world's poorest countries have the most menacing war machines. Ergonomics is not a panacea, but it holds a significant potential to betterment of life, more so by far in IDCs than in IACs.

34.5 Diverse Faces of "Sustainability"

Sustainability in IDCs means conservation and beneficiation of endemic natural resources and an assured increased market share for all in the global arena. Sustainability in IACs means retention of lifestyles, but only insofar as this can be achieved while actively

reducing the incurred "carbon footprint." In this regard, IACs have the more difficult task. Sustainable improvements in working conditions in IDCs imply, often naively, that there are indeed working conditions to improve—a concept readily grasped if one has a mental image of Darfur in mind.

Who in IACs pauses to consider the working conditions of the (often illegal) immigrants in their midst, who are exploited at below minimum wage rates, gratefully doing work endemic legal citizens shun as being beneath their dignity? The people concerned are escapees from countries which offer even fewer prospects and greater exploitation—the IDCs. Working (for next-to-nothing) in South Africa is better than dying (for nothing) in Zimbabwe or one of the "blood diamond" States of West-Central Africa. So it is not only a steady flow of the poor (seeking "better" jobs) from IDCs to IACs that the world is witnessing, but also a migration from poorer to relatively less poor IDCs, or from rural areas to urban centers within the same country, and the flow seems unstoppable. Sustainable positive change in the working lives of people globally roots these people where they are, in expectation of a better existence. This volume has talked of the parlous state of occupational health and safety in much of Mexican industry and of the dulling effect of social deprivation on the physical and mental work-performance of Peruvian workers. In South Africa, it would be true to say that the significant majority of workers face similar problems—and in Zimbabwe the challenge would be to find one who did not.

The motive behind technology transfer is self-serving: a means of expanding markets and simultaneously lowering production costs. There is no *quid pro quo*, no real concern for upliftment which benefits all in the very long run. Short-term gain with a "cut and run" escape clause is the ethos of the already advantaged. Yet we know how a deeper perspective could, were it taken, produce sustainable win–win outcomes for all concerned. Repeatedly we hear that sustainable change is not effected by outsider intervention of a once-off nature, but rather by the formation of in-house facilitation teams tasked to develop and oversee unremitting small but cumulative positive changes.

34.6 "Global" Ergonomics

Although the basic objective of ergonomics is the same for all (put simply, to make it easier to achieve more), with the very ambitious mission of the IEA "to enhance the quality of life for all," the truth is that a huge majority of the world's population has been marginalized by many of the leading ergonomists who are steeped in theory and high technology. Ergonomics has yet to become a ubiquitous global discipline. Surely it is opportune for the international body promoting ergonomics (the IEA) to recognize the need to put more of its resources into the development of ergonomics in these needy regions, where basic working conditions are so wretched. Ergonomics has been characterized as "human rights in the work place." If we really do believe that ergonomics has a role to play in addressing the inequalities in our world (see Scott, 2008 for more information on "Global inequalities"), then there is a need for a major paradigm shift in the international bodies associated with improving the well-being of workers around the world. We need to create a universal awareness of the realities so prevalent in IDCs. By drawing public and government attention to the situation, we might begin to awaken a global social conscience leading to the acts of social responsibility. Hopefully in the not too distant future, the IEA will have more federated societies from IDCs than from IACs. Maybe then, such a paradigm shift will eventuate.

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Ergonomics in Developing Regions
Needs and Applications

Industrially developing countries tend to have the largest populations, the highest levels of poverty, poor health, and illiteracy, and the greatest need for improvement in working conditions. And as the marketplace and the workforce go increasingly global, accountability with regard to the abuse of cheap labor in developing countries is becoming an issue. Presenting a global view of the state of ergonomics in industrially developing countries (IDCs), **Ergonomics in Developing Regions: Needs and Applications** identifies problems, offers solutions, and explores costs and benefits. It defines the steps that can be taken to close the gap between working conditions in affluent and deprived nations.

The book highlights the plight of millions of laborers and the poor working conditions pertaining to industrially less developed countries where the working environment mirrors the socio-economic deprivation of the people. Woven throughout the 34 chapters of this book is the tenet that good ergonomics is good economics. The chapters include examples of low-cost interventions at the work place in IDCs. The contributors discuss the ripple effect of ergonomics beyond the workplace to the betterment of life in general for the huge workforce in IDCs around the world. They focus on work-site problems and ergonomic solutions in developing regions around the globe, covering work conducted in Asia, Africa, South America, Russia, and China.

Examining factors unique to IDCs, leading ergonomists provide insights as to how sustainable progress is achievable in the developing world. They demonstrate the need for a more inclusive macro approach, citing managerial input essential for sustainable progress. With a panel of authors that reflects the multidisciplinary nature of the field, this book chronicles the nuances of differences in aim, practice, and outcome when ergonomists tackle developing world problems from a developing world perspective.

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